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MACHINE TRANSLATION OF ENGLISH NEWS TO INDIAN SIGN LANGUAGE (ISL) USING SYNTHETIC ANIMATION FOR DEAF COMMUNITY

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ABSTRACT

Communication of ideas, concepts, and knowledge to others depends heavily on language. A language known as sign language is used by hearing-impaired persons to comprehend our thoughts. Our created system in this study uses a rule-based methodology. Our method uses synthetic animations based on Indian Sign Language's grammatical rules to translate English news into ISL. Following identification, 141 grammatical rules that transform complex, compound sentences into simple ones are used. Lemmatization is used to transform the words into the lemma form because inflections of words are not used in ISL. The bilingual dictionary includes total 4497 gestures in the form of synthetic animation. Animated virtual avatars are used to convert the HamNoSys notations into synthetic animations. The survey was done in Patiala's "Deaf and Blind School of Patiala" to assess the created system. The performance of the system has been assessed using qualitative and quantitative metrics on a total of 1112 news phrases. It is demonstrated that the created English News Telecast System for Deaf is normally 79.94% accurate. The ISL lexicon and recorded ISL videos are compared to every signed word's output. This research contributes to the domain of sign language translation by merging established linguistic principles within new animation techniques. It represents a main step towards bridging the gap for ISL users, enhances their access to education, media and border societal participation.

General Terms

Keywords

BART, ISL, Deaf community, Synthetic Animation, HamNoSys code and SiGML Player

1. INTRODUCTION

Communication in the world stands as a fundamental basic human right, yet for the approx. 72 million deaf individuals worldwide, finds issues in accessing the information. In India, between 1 million to 2.7 million people mainly depend on Indian Sign language (ISL) for the communication (Kulkarni et al.). Despite this large population, there exist significant gap in information accessibility, mainly in news content, which is mostly available in spoken and written formats. Indian Sign Language, like other sign languages worldwide, is a rich visual-gestural language with having its own grammatical syntax, structure, and lexicon distinct from spoken languages (Núñez-Marcos et al.). The shortage of ISL interpreter is only in the few hundreds compared to the millions of potential users which widens this accessibility gap. Machine translation for Sign language represents a novel approach that combines Natural Language Processing (NLP) and animation to bridge this communication gap (Núñez- Marcos et al.). This approach consists of converting text or speech from a source language (English News) into a visual form of sign language through synthetic animations (Das Chakladar et al.). By using advanced models such as BART (Bidirectional and Auto-Aggressive Transformers), a powerful sequence-to-sequence architecture, we can enhance how deaf communities access information, mainly news content that shapes public discourse and civic participation. Research shows that English comprehension among deaf individuals is generally low in India (C. J. Sruthi and A. Lijiya). This communication lack not only restricts in information access but also restricts social participation and educational opportunities. The digital revolution has transformed information spread, yet these advancements have not equally helped all target population. For deaf community in India, English news content remains largely inaccessible due to language barriers and the limited presence of real-time interpretation services.

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The approach provides novel contributions to the domain of machine translation for sign languages. Firstly, the showcasing of the effectiveness of fine-tuning the BART model architecture mainly for English-to-ISL translation, using its pre-trained capabilities on large text to generate contextually accurate sequences. This represents a significant advancement over existing rule-based systems, mainly for handling complex sentence which are common in news reporting.

Secondly, the paper presents an innovative integration between the neural translation model and a synthetic animation system, creating a pipeline that preserves semantic content throughout the translation process. Our system uses HamNoSys notation which is converted to Signing Gesture Markup Language (SiGML) for animation.

The evaluation results reveal improvements over baseline approaches, particularly in handling complex synthetic structures. Furthermore, by focusing new content- a domain critical for awareness and participation-this research directly addresses information inequality. The main goal is not only technology innovation but also social impact through improvised communication access.Traditional approaches to bridge this gap depend on human interpreters or pre-recorded video, both have significant limitations in terms of scalability, cost-effectiveness, efficiency and real-time application (Adeyanjue et al.). Early computational methods utilized rule- based systems that faces issues with the linguistic complexity of sign languages which failed to capture the spatial Grammer and non-facial features to ISL.

2. REVIEW LITERATURE

The approach to translating English text into Indian Sign Language (ISL) using the BART model and synthetic animation offers major advantages over existing methods. Traditional ISL translation system mainly relies on rule-based systems which often limit flexibility and real-time processing.

The integration of machine translation for converting English news into ISL (Indian Sign Language) with the help of synthetic animation is a novel approach to improve usability for the deaf community. This literature survey compares research that explore various methods for ISL translation, identifying their contributions, limitations and research gaps while highlighting our proposed approach enhances upon them.

Many research has focused on developing automatic translation systems for ISL using text-to-sign conversion. Goyal and Goyal (2016) introduced a system that converts English sentences into ISL using synthetic animations, highlighting the importance for improved and accurate lemmatization and lexicon-based translation. However, this method was limited to preset sentences and lacked real- domain sentence conversion. Similarly, Kaur and Kumar (2020) designed a rule-based ISL translation system using Hamburg Notation and Signing Gesture Mark-up Language, still limited by set vocabulary. Krishna et al. (2020) provided an ISL interpreter that used animation for translation but lacked real-time adaptability and contextual understanding.

Recent advancements utilize neural networks and deep learning techniques to improve ISL translation. The GA-based ISL interpreter proposed by Devi et al. (2022) converts text from media files into ISL animations, still it mainly focuses on gloss-to-sign conversion in spite of direct English-to-ISL system utilizing Google cloud's speech recognizer API, attaining 77% accuracy but rest limited by its reliance on predefined phrase meanings. Likewise, Sharma et al. (2022) designed an NLP-based speech-to-ISL system, but it only generated outputs for database-matched sentences or words, limiting its applicability to further domains.

Some researchers have proposed thorough translation models integrating multiple parts. Sudiksha (2025) designed a real-time speech-to-ISL system using NLP techniques for context- aware translations, addressing the limitations of predefined phrase conversion. Similarly, Ghosh and Mamidi (2022) introduced a rule-based translation system with multi-word expression detection through it suffered from a limited vocabulary size. Carter (2023) developed a dictionary of 3051 ISL words using synthetic animations but did not evaluate the effectiveness of synthetic animations towards real human videos.

Despite these advancements, existing systems face significant limitations, including the lack of continuous synthetic animations, absence of contextual, grammatical accuracy and lacking coverage of real-domain sentences. Additionally, few studies address the integration of NLP (Natural Language Processing) with machine translation to generate accurate and natural ISL gloss sequences.

3. METHODOLOGY

The first part of the processing is the normal analysis of the input statement that is to be the given by the user. The raw statement that is given to input needs to be refined and then given to the methodological part for the major processing. Now the important thing is that before doing these things the model needs to be trained so in order to train that thing it needs to be broken and only the meaningful part is to be given to the methodological part for the accurate implementation.

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3.1 Data Collection

Already a lot of work has been done for the construction of sign language dictionaries. These dictionaries were created for the SL in variety of countries including China, Korea, the United States, and Vietnam hence proving that the dictionaries are reliable for the purpose of training the model at every step. The dictionaries are compiled by using all the necessary knowledge that is available and then integrating it with real human videos (initially) and 3D computer generated synthetic animated videos (nowadays used). Some of the notable work that has been done in the field of creating the ISL dictionary are as follows:

1. Cormier et. al. [5] prepared a BSL Sign Bank dictionary for BSL. It includes 2528 words of signs in the form of human video clips.

2. Goyal et. al. [8] developed an ISL dictionary using synthetic animations. The dictionary contains 1478 words signs in the form of 3D avatar animations.

3. Fuertes et. al. [6] developed bilingual dictionary for two languages which include Spanish Sign Language–Spanish (DISLE).

For the clarity purpose the dictionary that contains 1478-word signs in the form of 3D avatar synthetic animations are used in this purpose work of research to showcase the viability and the creation of the dataset for the purpose of the training and evaluation of the model at every step in the result section.

3.2 Data segmentation and Analysis

The data that is taken input from the user, it will be at first split into small sentences for the purpose of understanding by the model. The block of sentences will be taken as input from the user and after that, the spacy library will be used for the purpose of splitting the user input data into multiple small sentences in such manner that it will be easy for evaluation and segmentation. The major need for the breaking into small sentences for the usage of tokenization which is basically breaking down each and every sentence into singular atomic tokens basically words. The tokenization is done for the purpose of the fact that POS tagging can be done properly such that the POS tagging will result into the proper understanding of the sentence. To understand how a POS tagging works let’s take an example of the sentence: “The quick brown fox jumps over the lazy dog.”

Table 1 Shows the output of the POS tagging of a sentence

Word	**spaCy Tag**	**NLTK Tag**	**Meaning**
The	DET	DT	Determiner
Quick	ADJ	JJ	Adjective
Brown	ADJ	JJ	Adjective
Fox	NOUN	NN	Noun (Singular)
Jumps	VERB	VBZ	Verb (3^{rd} person singular present)
Over	ADP	IN	Preposition
The	DET	DT	Determiner
Lazy	ADJ	JJ	Adjective
dog	NOUN	NN	Noun (Singular)

3.3 Lemmatization

It is basically the process of converting each and every word to tis lemma form. The lemma form means that inflected forms are converted to the original base dictionary format for the proper understand of the language. The ISL dictionary which is made contains all the words in the lemma form and as a result it is needed to be made to its lemma form for the purpose of smooth translation in the HamNoSys code at the end part. The accurate working of the BART model is also necessary for the purpose of the fact that it will help in proper evaluation as the two-way input format is obtained in this

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process. It is imperative to understand that when a block of English texts is given as input from the side of the user, it will take every sentence and will convert it to the most simplified version according to the ISL grammatical format and then give it to the methodological implementa-tion part. The number of lists will be determined by the number of simplified sentences that are being developed.

3.4 Methodological Implementation

The conversion to the English phrases or the block of English text to the animated version is done with the help of the fact that the text is predefined and preprocessed and free from any kind of bugs. The English text is preprocessed and a modified English text is generated which is the text that is obtained through the data preprocessing pipeline. The data preprocessing pipelines splits the text into sentences, removes extra symbols and simplifies the long or com-plex sentences by lemmatizing the words by reducing them to their base form. The output given after the preprocessing text is a simple refined list of sentences that is ready for the pur-pose of translation by going through multiple process of the architecture at any moment of time. The ISL is used here which does not support complex sentences, so a prep processed structured sentence is necessary for input to the model (BART) which can handle it efficient-ly.

The methodological implementation of the BART model requires a series of steps that is needed to be done, which included the following steps:

1. Pair Data for Input: Data is made ready for the input to the model.
2. Input into BART Model Architecture: The architecture is given the input which will take it and give the required output.
3. Generate Token Sequence from Decoder Output: The token sequence is generated from the decoded output which is basically the last phase of the BART model.
4. Append ISL Token Sequence: The Token sequence that is generated is appended here, one by one the token sequence that gets generated is for made to wait and then merged at this point.
5. Text to HamNoSys: The appended text is now taken to convert into HamNoSys nota-tion by mapping to the ISL tokens.
6. SiGML Rules: SiGML (Signing Gesture Markup Language) is used here to mark the ISL language and then used for the fact that to create interactive and visually appealed images for the purpose of the making the animation smoothly.
7. Synthetic Animation: The SiGML player is given a final script on which it takes to give the output which is basically visually animated for the purpose of the showing case which is easy to store and much better than the human version of the storing of the human -signers.

The above steps are followed rigorously to each and every step such that these steps lead to the conversion of each and every sign to the animated version of the ISL dictionary at any moment of time leading to a successful implementation. The below image shows the structured workflow of the process leading to the efficient processing of the model.

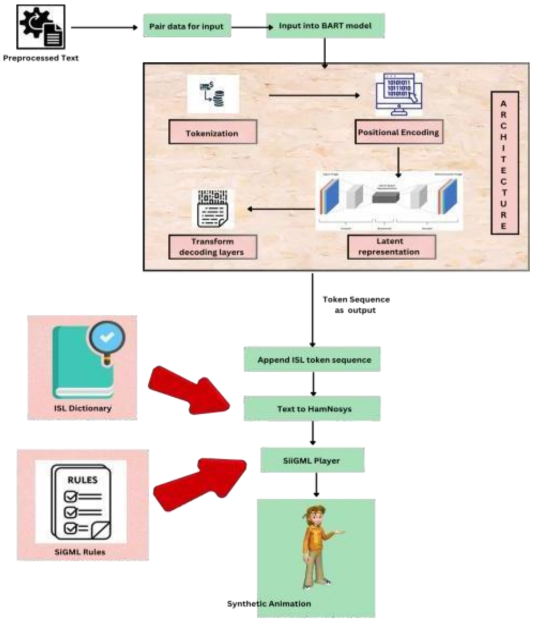

Figure 1 Methodological implementation

The preprocessed text that is taken as input from the NLP preprocessing pipeline is now done with the purpose of the fact that it is now given to input to the model for the purpose of the training in a smooth manner. During training phase only, pairing of the English text with the corresponding ISL data is needed for the purpose of the fact that it can be mapped to the ISL token sequence. This phase is done only during the training part by matching the data parallel to make the model understand how to map English sentences to the ISL token se-quence. Training batches that can be fed into the BART model to learn the translation task are the output for the next phase of the process in which the input is given for the process of smooth learning and training of the model. This phase is very important as the supervised learning environment is maintained where the model can compare its predicted ISL tokens against correct ones.

3.5 BART architectural process

The major and the most significant part of the process is the sequence-to-sequence (Seq2Seq) Transformer that excels at text generation and translation tasks. The model which is used here is the BART model that can handle noisy and complex inputs due to its bidirec-tional encoder and autoregressive decoder. This makes it well-suited for translating from Eng- lish text to ISL tokens. The simplified English sentences are given as input but during the training phase the paired data is given as input. Internal hidden representations (encoder out- put) and eventually an ISL token sequence (decoder output) are generated which are going to be appended in the next sections There are multiple parts of the BART architecture that is needed to be gone though one by one which are as follows:

- Tokenization: Breaks the sentence into smaller units. This is the first phase of the BART architecture by taking in the single sentences as input and then a list of tokens is generated.

- Positional Encoding: The positional encoding is done for the purpose of the fact that so that the word order is preserved which is very crucial for the meaning of the sen-tence and the conversion to the ISL structure.

- Decoding Layers: The BART model is the bidirectional model that processes the dual encoding and decoding facility.

- Lateral representation: The vectorization is done at every step for the purpose of un-derstanding but the meaning before the ISL tokens is generated needs to be secured.

3.6 ISL Token Sequence

The most important part of the process is to store the newly generated ISL token sequence to a collection of lists. If there is a processing of multiple sentences which is basically the block of English statement in that scenario a larger structure containing all the generated to-ken sequences are present the accumulation of all the ISL tokens is very necessary for the fact that a sensible and movable animation is made for the better purpose of the understanding. One by one the ISL token sequence will come and then merging of the token sequence of the ISL is done is this part.

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To understand the fact that the ISL tokens that are generated from the above noble process, these are taken as input and are stored in a list. This list is first checked is empty or not if it is empty the first ISL token sequence is appended. The process I cleared after every English block of token converted ISL token sequence is transferred to the next phase and as a result there are not previous sentences stored in the list. The beauty of this process is that the ISL token sequence is then given to the process of generation to HamNoSys.

3.7 HamNoSys and SiGmL Player

HamNoSys is a specialized alphabet that captures the orientation, position and motion of hands, plus non-manual elements like the facial expression. This HamNoSys is a recognized language- independent way to describe signs for the purpose of conceptual use.

After the generation of the ISL token sequence is done, it is appended, the appending re-sults to the full ISL token sequence in which the synthetic animation is to be made. In this step mapping of ISL token to its corresponding HamNoSys notation is done by taking the full sequence if ISL token sequence and then generating a parallel list of HamNoSys codes.

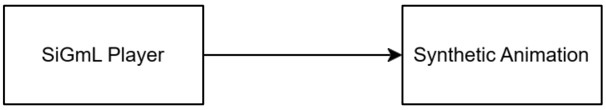


Figure 2 Block Diagram of Synthetic Animation Conversion

SiGML (Signing Gesture Markup Language) is an XML- based representation that 3D ava-tar systems can read to animate the signs. This system is widely supported by sign- language animation engines for bridging the gap between symbolic notation (HamNoSys) and an actual animated synthetic performance. Synthetic animation is more flexible and storage-efficient than recording human signers for every possible word. This step is essential for the purpose of the generation of the synthetic animation as a result the non- manual cues are generated for creating the actual animated performance. In this phase the relevant SiGML rules are applied to each and every HamNoSys code. This part takes in the relevant HamNoSys code for input and then a proper output of the SiGML script is generated at first. This script is precise and it describes how each sign should be animated, including the timing, translations and non-manual cues.

After generation of the script, it is fed to the SiGML Player that reads the SiGML script and renders a virtual avatar performing the different signs. The final SiGML file script is given as input and a visual, animated performance of the translated ISL showing each sign in sequence is shown showing all of the conversion in a sequential manner. The final user-facing output is shown which is basically a signing synthetic, animated avatar performing the ISL correspond-ing the original block of English Text.

4. RESULTS

The evaluation of research work is most important aspect that gives insights into the effec-tiveness and potential impact of the research.

Intelligibility Test: This test considerate the result of the translator. It is examined with the help of output sentence without being aware of input sentence. Therefore, this test is demon-strated by the individuals which are familiar with the ISL (Indian Sign Language). With the help of four-point scale, the test sentence's understandability was evaluated.

Table 1 Four-Point Scales for Intelligibility Test

Score	Significance
3	The sentence is highly intelligible.
2	The sentence is intelligible but has some Inaccuracies.
1	The sentence contains grammar errors and can be Understood only after some study.
0	The sentence is unintelligible (not understandable).

So, after the evaluation out of 1112 test sentences, 889 (79.4%) are understood (whether accurate or inaccurate), 142 (12.76%) were intelligible with some errors. 40 (3.59%) sentences were not understandable properly. This is done to see if the translation of the relevant refer-ence has been correctly understood or not.

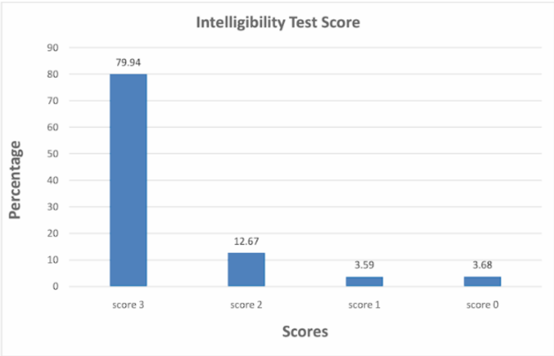


Figure 3 Bar Graph Representing Outcomes for English News to ISL

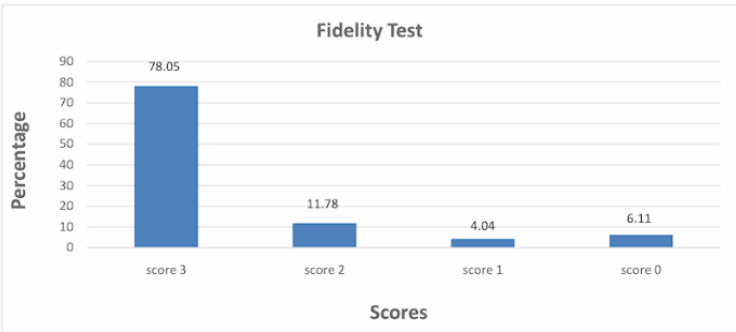
Fidelity Test: It also knows as the accuracy test. It is used to determine how much infor-mation was preserved in the translation of a sentence compared to the source text.

It is also evaluated on the four-point scale.

Table 2 Four-Point Scales for Fidelity Test

Score	Significance
3	Totally Accurate
2	Moderately Accurate
1	Hardly Faithful
0	Totally Inaccurate

Out of 1112 sentences of testing data, 868 (78.05%) sentences were correct, out of which 131 (11.78%) sentences were moderately correct and these were regarded as accurate sentences. 45 sentences (4.04%) were not deemed to be correct. The total number of 68 (6.11%) sentences were not converted or taken as incorrect sentences.



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SER: SER stands for Sentence error rate which is the proportion of MT output sentences that does not matched the reference sentences to all of the reference sentences.

SER = Number of unmatched sentences / Total number of Reference sentences

$$SER = 113/1112$$

113 sentences out of 1112 sentences were measured as incorrect so the SER is 0.10%.

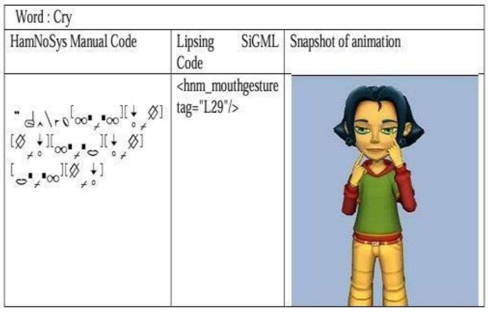

Figure 4 Snapshot HamNoSys Code, Lipsing SiGML code of word cry

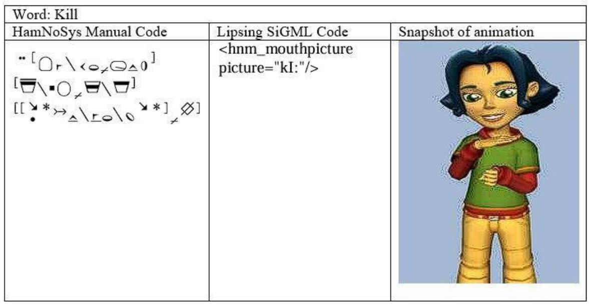

Figure 5 Snapshot of HamNoSys Code and Lipsing SiGML code of word kill

5. **Future Work**

Upcoming research should focus on the solving the current limitations and enhancing the accuracy and usability of machine translation framework systems for ISL.

Key domain areas of focus involve:

a) Expanding the Datasets: The making of larger and more different datasets is important for enhancing the accuracy and performance of machine translation systems.

b) More advanced animation techniques: The usage of more advanced animation technolo-gies like 3D modelling, motion graphics and many more can improve the realistic and expressiveness of syntactic animation.

c) Integration of new upcoming technologies: The integration of machine translation sys-tems with emerging technologies like deep learning and computer vision which can im-prove the performance and accuracy of the system.

d) Real-time Interactive Systems: Designing real-time interactive systems that can translate spoken or written English into ISL via AI-powered animation which improve

e) accessibil-ity in live settings like classrooms, workplaces and public work areas.

f) Performance: Enhancing the processing speed with minimum latency is a crucial re-search focus.

g) Personalization: Upcoming systems can be capable of personalized ISL translation based on user preferences, regional dialects and learning. As it can ensure more user- friendly and context-aware communication based on individual needs.

h) Cross-platform Integration: Ensuring integration of ISL translation technology between multiple platforms with mobile apps, web browsers and smart devices which can maxim-ize its usability. Compatibility with technologies like screen readers and braille device can further improve accessibility.

CONCLUSION

Human evaluation is the most effective method for the evaluation of machine translating systems as it captures the nuances of languages like idiomatic expressions, cultural references and many more. But as we know that human evaluation is more time-consuming and costly. For the evaluation of our English news to ISL MT systems we used both qualitive and quanti-tative metrices to check its overall accuracy which is approx. 80%. The machine translation of English news into ISL (Indian Sign Language) with the help of synthetic animation is a huge complex but rewarding task that has the ability to enhance the life of the Deaf community. By using the advanced technologies like Natural Language Processing (NLP), computer vi-sion, machine learning (ML) and researchers can design most accurate and user-friendly framework that bridge the communication gap between Deaf individuals. Continues research and development in this domain are important for overcoming recent challenges and knowing the full ability of ISL translation technologies.

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