English To Indian Sign Language: Rule-Based Translation System Along With Multi-Word Expressions and Synonym Substitution

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Abstract

The hearing challenged communities all over the world face difficulties to communicate with others. Machine translation has been one of the prominent technologies to facilitate communication with the deaf and hard of hearing community worldwide. We have explored and formulated the fundamental rules of Indian Sign Language(ISL) and implemented them as a translation mechanism of English Text to Indian Sign Language glosses. According to the formulated rules and sub-rules, the source text structure is identified and transferred to the target ISL gloss. This target language is such that it can be easily converted to videos using the Indian Sign Language dictionary. This research work also mentions the intermediate phases of the transfer process and innovations in the process such as Multi-Word Expression detection and synonym substitution to handle the limited vocabulary size of Indian Sign Language while producing semantically accurate translations.

1 Introduction

There are more than 300 sign languages all over the world, depending upon the region of the world (uni). Nearly 4 million deaf people and more than 10 million hard of hearing people in India (Zeshan et al., 2005). Out of such a big number, approximately 1 million deaf adults and around 0.5 million deaf children in India use Indian Sign Language. Rest of nearly 2.5 million deaf and hard of hearing people do not use any sign language to communicate. Thus nearly 80% of hearing-impaired individuals have very limited or no access to education and other information. Hearing-impaired people use sign language using handshapes, fingers, facial expressions, gestures, and other body parts. It is a visual-spatial language as the signer often uses the 3D space around his body to describe an event. Sign languages, until the 1960s, were not viewed as bona fide languages but just collections of gestures and mime. Dr Stokoe's research on American Sign Language proved that it is a full-fledged language with its own grammar, syntax, and other linguistic attributes (Stokoe, 1960). There are some efforts to prove the same for other sign languages, including Indian Sign Language.

The sign language used in India is Indian Sign Language (ISL). A study by (Vasishta et al., 1980) specifies that the ISL used in different parts of India is almost identical in its structure, with differentiation in signs. It is a social need to encourage the hearing impaired individuals of the Indian subcontinent with a tool that can translate the English text to ISL. ISL has all the properties of a natural language and is also considered a natural language like British Sign Language (BSL), American Sign Language (ASL), and Australian Sign Language (AUSLAN). The idea of automatic machine translation in the area of Sign Language translation has been developing very fast in the last two decades as the technology needs to be used for the hearing impaired people all over the world. Most of the researchers experimented with the rule-based machine translation methodology to translate a spoken or written language to Sign Language as this method relies upon the dictionary and the grammar of the source and target languages. Rule-Based Machine Translation is mostly used these days as Indian Sign Language is a low resource communication system and there is a lack of content published in Indian Sign Language. The current state of the art system is described in (Sugandhi et al., 2020) which is also a rule based system. We have tried to improve upon their work.

2 Goal of the Study

The objective is to take a standard English sentence and convert it to text for sign language. The text for sign language represents the given sentence so that anyone can use it to perform the required gestures. This text for sign language can be then used to automate the process of generating sign language

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videos.

Up till now, most research has focused on the grammar rules. (Agarwal et al., 2015) and (Mishra, 2019) contain extensive lists of grammar transfer rules but this method for a large part has been restricted to very simple sentences. We try to tackle more complicated sentences here which are simple in structure but some of the meanings conveyed by them are complicated and the previously used methods fall short in some regards. We have therefore used approaches such as Multi-Word Expression detection and Synonym substitution to handle hidden meanings within the sentence structure. Not much work has been done in these areas in this field. (Goyal and Goyal, 2016) have used synonyms before but the methods used by them for synonym substitutions are limited by the size of their manually created dictionary of synonyms for certain words. We have used existing English WordNet described by (Miller et al., 1990) for finding synonyms.

3 Methodology

We have broken down the steps into 3 phases: Pre-processing, Grammar Transfer Rules and Post-Processing. We are using Stanza by (Qi et al., 2020), which is a collection of accurate and efficient tools for the linguistic analysis of many human languages. It is created by the Stanford NLP Group. Apart from this, we are also using MWE tokenizer from NLTK by (Bird and Loper, 2004) for MWE tokenization.

3.1 Pre-Processing

In pre-processing step, we take each sentence and pass it through two processing pipelines:

1. First pipeline is the standard Stanza Pipeline described in (Qi et al., 2020) and includes the steps of Tokenization, POS tagging, Dependency Parsing, Named Entity Recognition and Lemmatization.

2. The second pipeline uses the jMWE dataset created by (Kulkarni and Finlayson, 2011) along with the MWETokenizer available as a part of the NLTK project by (Bird and Loper, 2004)

3.2 Grammar Transfer Rules

Here we are trying to convert dependency relations to syntactic relations. The dependency relations in the source language are defined as:
$parent\ \ node(parent\ \ dependency) \rightarrow child\ \ node(child\ \ dependency)$ which are then converted to syntax tree fragments with the notation
$phrase\ tree\ branch \rightarrow (left\ node)(right\ node)$

1. Source: $VERB(root) \rightarrow NOUN(obj)$
   Transformation: $VP \rightarrow [NOUN(obj)][VERB(root)]$
   Example: $He\ \ eats\ \ mangoes \rightarrow HE\ MANGO\ EAT$

   Explanation: Since ISL follows SOV structure, the sentence arrangement should be NP NP VP. That is why we put all the nouns to the left of the verb.

2. Source: $VERB(any) \rightarrow AUX(aux)$
   Transformation: $VP \rightarrow [AUX(aux)][VERB(any)]$
   Example: $He\ \ was\ \ eating \rightarrow HE\ WAS\ EATING$
   All auxiliaries to a verb come before the verb

3. Source: $VERB(any) \rightarrow ADV(advmod)$
   Transformation: $VP \rightarrow [VERB(any)][ADV(advmod)]$
   Example: $He\ \ ran\ \ quickly \rightarrow HE\ RUN\ QUICKLY$
   Explanation: All adverbs to a verb come after the verb

   Note: Rules 2 and 3 would not have appeared in syntactic transformation rules because they do not change the order of the syntax tree. But since we want to extend this to other languages, we need to specify where each child node goes wrt to the head node.

4. Source: $VERB(root) \rightarrow VERB(any)$
   Transformation: $VP \rightarrow [VERB(root)][VERB(any)]$
   This case is written to handle multiple clauses in a sentence. In case of multiple clauses in a sentence, the clauses will be processed in order.

5. Source: $NOUN(any) \rightarrow ADJ(amod)$
   Transformation: $NP \rightarrow [NOUN(any)][ADJ(amod)]$

Example: $He\ has\ a\ blue\ book \rightarrow HE\ BOOK\ BLUE\ HAVE$
Explanation: Adjectives follow the noun they describe

6. Source: $NOUN(any) \rightarrow NUM(nummod)$
Transformation: $NP \rightarrow [NOUN(any)][NUM(nummod)]$
Example: $He\ has\ three\ sons \rightarrow HE\ SON\ THREE\ HAVE$
Numbers are handled in two ways in ISL:
   (a) Reduplication: Repeat the noun to signal plurality
   (b) Numbers follow the noun denoting the quantity

7. Source: $NOUN(any) \rightarrow ANY(acl : relcl)$
Transformation: $NP \rightarrow [NOUN(any)][ANY(acl : relcl)]$
Example: $I\ saw\ the\ book\ which\ you\ bought \rightarrow I\ BOOK\ YOU\ BUY\ SEE$
Explanation: A relative clause is similar to an adjective and hence it comes after a noun.

3.3 Post Processing

Till this stage we have a rough ordering of the signs we need to show. In post processing, we handle special cases, filter out the unwanted words and reduce the words to their root forms.

3.3.1 Interrogative Sentences

Interrogative sentences are signed by first showing the signs of the sentence converted to the imperative form followed by the question word. These question words usually do not have a specific dependency role assigned to them and can occur in many relations depending on the type of sentences. Apart from this, it also becomes very difficult to judge whether or not a wh-word used in a sentence is a question or not, e.g. $I\ know\ what\ he\ is\ talking\ about \rightarrow I\ HE\ TALK\_ABOUT\ KNOW$. In this sentence, the word what is a wh-word but is used as a conjunction. Similarly, questions may sometimes be formed in English without using a wh-word, e.g., $Did\ you\ do\ your\ homework \rightarrow YOU\ HOMEWORK\ DO\ WHAT$. This problem has been extensively discussed by (Aboh et al., 2005) It is difficult to handle such cases, and what we have tried to do is just take the wh-word and pick it and place it at the end of the sentence.

3.3.2 Negative Sentences

Negative sentences are sentences that have a not or no in them. They convey the meaning that the opposite of the event occurs. We apply a similar strategy for negative sentences by just picking and placing the negative word at the end of the sentence, e.g. $He\ is\ not\ a\ doctor \rightarrow HE\ DOCTOR\ NOT$. Similar strategies would work well with other languages too.

As we see, negative sentences and questions are handled similarly in ISL. But then the question arises: If we have a negative question sentence such as $Who\ will\ not\ come\ with\ me$, how is it signed in ISL. We did not find any literature discussing this. So we contacted ISLRTC, and their group of expert signers seemed to sign the negative word before the question word. So the previously mentioned example would be translated as $Who\ will\ not\ go\ with\ me \rightarrow I\ WITH\ GO\ NOT\ WHO$

3.3.3 Synonym Substitution

As we have mentioned earlier, Indian Sign Language is still new, and many terms are yet to be added to the dictionary. As such, till now, there are only 10000 words in the ISL dictionary. As a comparison, English has around 200,000 words (Brewer, 1993) which is 20 times the size. Hence, there are many words in English that do not have an equivalent sign. If such a word occurs in a sentence, it needs to be translated somehow. For that, we substitute those words that are not in the video dictionary with words close to the original word's meaning and have a corresponding word in the dictionary. Closest words are selected from the synset in the WordNet based on a score denoting how similar two word senses are, based on the shortest path that connects the senses in the is-a (hypernym/hypnoym) taxonomy.

3.3.4 Stopword Removal and Lemmatization

After all the above processing is done, we need to clean up the sentences. ISL does not contain words such as articles and certain functional words that do not necessarily convey meaning. But not all stop-words in English are removed from ISL. For this purpose, we created our own list of stop-words for English based on inputs from translations of sentences in our dataset by expert ISL signers. Followed by the removal of the stop-words, we convert all the remaining tokens into their root forms. At the end of this step we reach the point where we are

ready with a textual representation of the videos required to be shown for translating the sentence.

3.3.5 Video Translation

After the sentences have been converted into text for sign language, the output tokens are then searched for in the video database. Two cases can arise here; one is that the tokens are available in the database. If the tokens are not available in the database, then we use WordNets to check if there are synonyms for that given word that have the same POS and are present in the dictionary. We assume that if the word has the same POS and is of similar meaning, it can be directly replaced by the synonym word without affecting the grammar. This is corroborated with evidence from the hearing impaired community. If any of the words' synonyms are not found in the dictionary, then that sentence cannot be translated into ISL, unfortunately, and there is little we can do about it. One possibility is to fingerspell the word, but that approach does not give accurate results always. We then concatenate the video for each sign together to generate the final output.

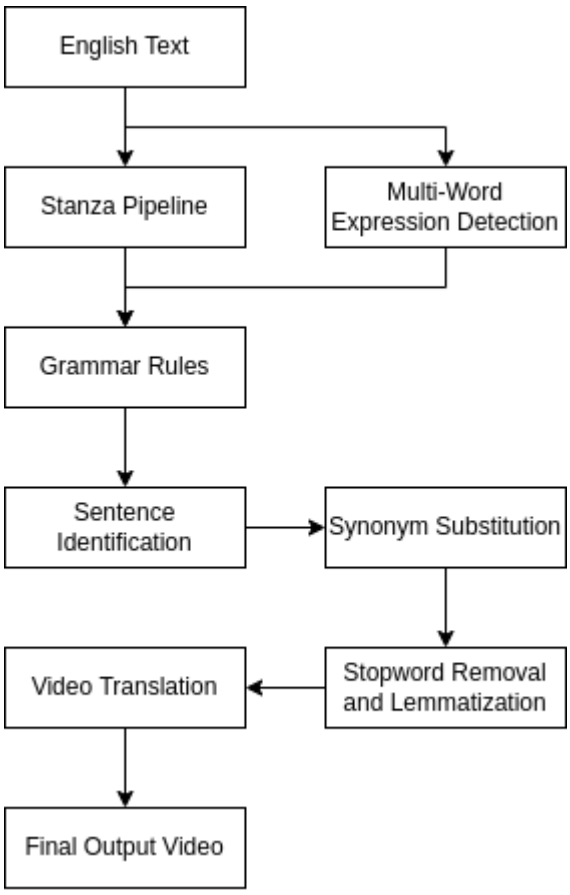

Figure 1: End-to-end System Diagram

		Accuracy
Total Sentences Checked	741	
Sentences with synonyms substituted	304	
Sentences with MWEs detected	24	95.8333

Table 1: Summary of results

4 Results and Discussion

As there was no previously established standard for this task, we selected the simple-wiki-dataset. We ran our model on 741 sentences with lengths of about 5-9 words per sentence. The results were manually evaluated.

4.1 Synonym Substitution

1368 words were substituted by synonyms in 1011 sentences. Some of the substitutions were very accurate. Such as raise→lift, argument→debate, survive→last, astound→amaze, etc. However, not all substitutions were meaning conserving eg. sword→steel, offend→break. Sometimes the substitutions were wrong because the meaning of the sign and the word were totally different. For example in some sentences, *say* became *'state'* but the sign for *'state'* is for the noun *state(country)* and not the verb *state* which actually would have shared the same meaning. Some examples are shown in Table 2

4.2 MWE Processing

There were 426 words in which were identified as Multi-Word Expressions. All of the MWEs identified were correct. Example: $look\_up\_to$, $rolling\_stock$, you_know, $thank\_you$, etc.

5 Conclusion and Future Work

In this paper we have tried to tackle semantically complex sentences and we see that the previously used methods fall short in some regards. Therefore, we have used approaches such as Multi-Word Expression detection and Synonym substitution to handle hidden meanings within the sentence structure. We needed simple English sentences to test out our algorithm, as the rules worked best for simple sentences. In future, we intend to use machine learning approaches to do the translations on a large dataset to convert the standard English sentences. The methods mentioned in the paper could be a way to convert a large dataset of sentences on which Deep Learning models such as sequence2sequence and transformers can be trained.

Sentence	After Grammar Rules	Missing Words	Replacement Word	Final Output
A woman sells newspapers	Woman newspaper sells	newspaper	paper	woman paper sell
Helene let her fall	Helene her let fall	let	allow	H E L E N E mine allow fall
This foreshadows later events	This events later foreshadows	foreshadow	predict	this event late predict

Table 2: Result of Synonym Substitution

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