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Rule-Based Machine Translation for the Automatic Translation of Vietnamese Sign Language

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Abstract: Sign language is acknowledged as a unique language in the field of machine translation, possessing distinct grammatical characteristics compared to written or spoken Vietnamese. These include simplifications, altered word order, and emphasis on stress. This article explores a rule-based machine translation approach specifically designed to translate Vietnamese utterances into grammatically accurate Vietnamese Sign Language sentences. While considered a conventional technique, this approach demonstrates remarkable success in this specific scenario. Evaluation results reveal that the proposed method outperforms several contemporary machine translation models for this particular challenge, achieving a BLEU score of 62.55. This achievement is particularly noteworthy considering the limited resources available for Vietnamese Sign Language. Moreover, experiments conducted with varying data sizes further solidify the effectiveness of this method within a defined domain. Notably, the BLEU score surpasses expectations for typical translation problems, highlighting the effectiveness of both the probabilistic model and the intuitive linguistic model employed. This study demonstrates the potential of rule-based machine translation for Vietnamese Sign Language, particularly in situations where resources are limited. The encouraging results pave the way for further research and development in this area, ultimately aiming to improve communication and accessibility for the Vietnamese deaf community.

Keywords: Natural Language Processing, Machine Translation, Rule-Based, Low-Resource Language, Sign Language

1. Introduction

Sign language is a language that employs hand gestures and facial expressions instead of vocal sounds. The deaf population has its own sign language as a means of social interaction and acquiring information. Sign language is acknowledged as a distinct language, independent from spoken language, and is used by deaf communities around the world [1]. For instance, British Sign Language and American Sign Language are autonomous languages with distinct phrases and grammatical structures compared to English. Indian Sign Language and Hindi are not the same, just as Thai Sign Language and Thai are different. Vietnamese Sign Language (VSL) is also regarded as a separate language with a unique grammatical structure. VSL serves as the official language for the approximately 7.5 million Vietnamese deaf population. If sign language is not understood and interpreted, enormous communication difficulties arise, just as with any other foreign language.

Due to advancements in machine translation and speech processing, automated translations between certain languages using templates developed by major corporations like Google have become viable. These techniques can also be extended to sign languages by integrating them as either source or target languages in translation models. This allows for the ambitious goal of attempting end-to-end translation between spoken language and sign language, or between sign language text and spoken language [2].

However, the application of these models to translating Vietnamese sign language poses significant challenges. The distinct grammatical structure and intricacy of the Vietnamese language, along with the representation of sign language, make it difficult to effectively utilize these methods for accurate translation. As a result, specialized and innovative approaches are necessary to address the complexities involved in translating Vietnamese sign language with precision and efficiency.

The sign language interpretation process involves two main problems: translating sign language into regular spoken/written language and vice versa. Figure 1 illustrates these two dimensions of the sign language automatic translation problem. The translation from sign language to regular language is crucial for conveying information and facilitating social inclusion for the deaf community. However, for the scope of this study, the focus will be solely on addressing the challenges related to problem 2, which involves translating regular spoken/written language into sign language.

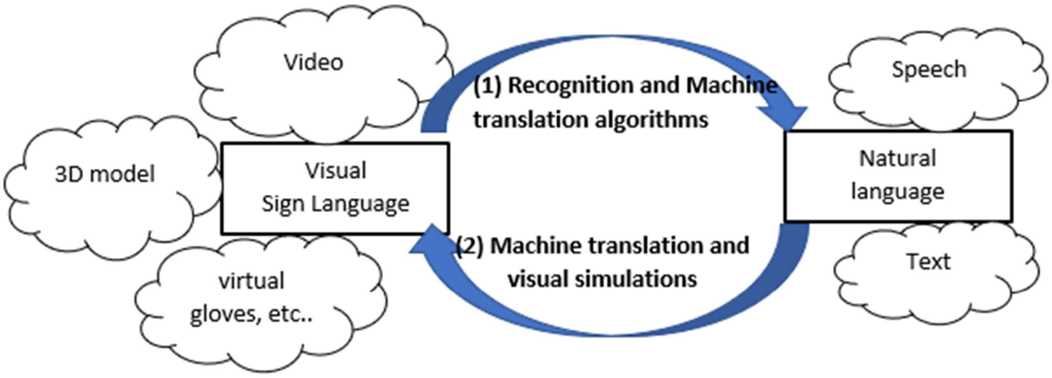

Figure 1. *Two dimensions of the sign language automatic translation problem.*

The VSL translation challenge involves taking a regular Vietnamese sentence as input and producing photos, videos, and 3D visualization models as output. However, a critical stage in this translation process is converting the ordinary Vietnamese phrases into grammatically accurate VSL sentences. This is crucial because VSL possesses essential characteristics, such as simplification, emphasis, and syntax transformation. Moreover, representing the grammatically accurate VSL phrases as visuals and 3D models follows the suggested technical approaches and yields positive outcomes [3]. Throughout this article, the focus will solely be on the translation of standard Vietnamese sentences into the appropriate syntactic form of Vietnamese sign language. This emphasizes the importance of ensuring accurate grammar and structure to effectively convey the intended meaning in sign language.

Due to significant advancements in information technology, various sign language translation systems have been developed worldwide. For instance, TESSA focuses on translating from speech to British Sign Language (BSL) [4], ViSiCAST translator translates from English to British Sign Language [5], The SignSynth project uses the ASCII-Stokoe model [6], the ASL workbench system provides automatic text translation into American Sign Language [7], and Project TEAM is a text-to-American Sign Language translation system using synchronous techniques.

Recently, Gouri Sankar Mishra and colleagues conducted research to translate spoken English into Indian Sign Language (ISL). They employed a parser to parse entire English sentences and derived dependency structures from the parse tree to represent syntactic and grammatical information. A multilingual ISL lexicon and a word network were utilized to develop ISL Sentence Reduction, and this resulted in the presentation of annotated ISL text along with its corresponding ISL signs [8].

However, applying these previous methods to the translation of Vietnamese sign language poses challenges due to the unique grammatical structure of Vietnamese sign language. Additionally, there is currently no comprehensive investigation with positive results for this particular problem. Thus, it is evident that more specialized research and innovative techniques are required to effectively tackle the translation challenges specific to Vietnamese sign language.

Recent research in the fields of Natural Language Processing (NLP), Deep Neural Networks (DNN), and Machine Translation (MT) is capitalizing on the latest technical advancements. The primary objective of this research is to develop advanced systems capable of translating between signed languages (SL) and spoken languages. The ultimate aim is to bridge the communication gap that exists between communities that use sign language and those who communicate using vocal language [9].

Galian et al tested two NMT constructs with optimization of hyperparameters, several tokenization methods, and two data enhancement techniques (decompile and interpret). Through the experimental process, they achieve a significant improvement for the models trained on the Phoenix 14T dataset and the DGS for German Sign Language [11].

Following the research on signing avatars by Kacorri et al [12], acceptance within the Deaf community is vital for the adoption of sign language generation technologies Aacceptance within the Deaf community is vital for the adoption of sign language generation technologies. The Deaf user perspective has to be properly analyzed and that enforcing technology on the Deaf community will not work [13]. Obstacles do not only include technological issues but also interdisciplinary considerations of development, evaluation and adoption of such technologies. Another important issue is how to evaluate and apply those technologies [14]. When the challenges can be resolved, opportunities for automated sign language translation systems are enormous. Especially a standard notation and bigger sign language datasets could significantly evolve training and performance of sign language recognition and generation technologies [15]. They would also entail numerous advantages of their own – such as a written form of sign languages, accurate dictionaries and better resources for learning sign languages [16].

We initiate our investigation with the rule-based translation methodology, despite the fact that several sophisticated strategies, including rule-based and statistical translation, or both, have been established for modern machine translation techniques. Statistical machine translation systems have the benefit of not requiring explicit programming of language rules, but they require a substantial quantity of bilingual data to achieve accurate translations. Our study on Vietnamese sign language is still in its early stages, and there is insufficient data for our topic, thus we employ a rule-based translation strategy.

2. The Proposed Method

2.1. Background

Contemporary translation models often rely on statistical methods, but the popularity of neural network models has risen, especially with the advent of Neural Machine Translation (NMT). NMT involves modeling the entire machine translation process using a large artificial neural network. Unlike traditional statistical methods, NMT employs a multilingual input corpus and retains all information from the input phrase at each time step, t. This allows for the semantic prediction of the target word to be computed using the context of the entire phrase, resolving the local context issue.

NMT represents the entire translation process, from input text encoding through decoding to identifying the optimal translation, using a unified model with shared parameters. This makes parameter adjustments easier and has shown great success in machine translation for various language pairings, including English to Vietnamese, Vietnamese to Japanese, and more. Similarly, in automatic sign language translation, contemporary models like the Transformer have been applied to Japanese sign language and German sign language translation [17].

One limitation of these contemporary models is that when new data is added, the model often needs to be retrained from scratch or requires significant additional training time. In contrast, rule-based machine translation techniques readily address this issue. Rule-based methods involve a set of morphological, syntactic, and semantic rules between source and target language pairings, which is especially useful for resource-less languages like Vietnamese Sign Language (VSL). However, rule-based translation systems face challenges due to the grammatical diversity of language pairings, as there is no comprehensive set of rules for all language pairs.

Despite these challenges, rule-based translation methods can be suitable for certain small machine translation systems that require minimal resources. For VSL, which lacks abundant resources, this approach can be particularly relevant. Most rule-based machine translation systems parse the source text, construct an intermediate symbolic representation, and then generate the target language translation. The process involves mapping between the dictionary's lexical items and the rules to explain the structural differences between the two languages. Since Vietnamese and VSL have substantially related syntax, various parsing strategies can be employed for translation [18]. The overall structure of a rule-based translation system is illustrated in Figure 2.

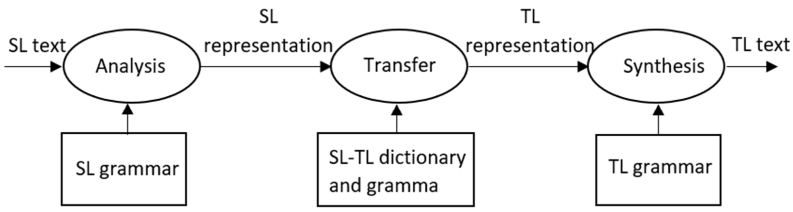

Figure 2. *Hierarchical structure of WordNet.*

2.2. Rules of Translation

Based on the findings of several studies conducted by VSL specialists [19], the key features of sign language syntax are as follows: (i) simplification, (ii) stress on emphasis, and (iii) changes in syntactic structure compared to ordinary Vietnamese. These essential characteristics have been summarized and documented in published studies [20, 21].

(i) Sign language is characterized by its simplicity. The vocabulary used by the deaf community is significantly smaller than that of standard Vietnamese. Consequently, when expressing themselves in VSL, deaf individuals use shorter and simpler sentences. This particular trait makes the translation task akin to text summarization. However, the translation challenges for VSL differ from those encountered in text summarization in features (ii) and (iii).

(ii) Stress on emphasis in VSL aims to deliver essential information first and draw greater attention. For instance, in the sentence "Thai Nguyen is renowned for serving the finest tea in Vietnam," the emphasized terms are "Thai Nguyen," "renowned," "tea," and "finest."

(iii) The change in syntactic structure also involves positioning the most crucial information at the beginning of the phrase. VSL's unique grammar rules dictate syntactic structures with modifications. For example, in questions, the question word is always placed at the end of the sentence. Thus, the Vietnamese sentence "Who eats apples?" becomes "apple eat whom?" in VSL.

In summary, Vietnamese-VSL translation can be guided by the following rules: ".

Rule 1: Shorten

All the words listed in the table are shortened (removed from the sentence).

Table 1. *Words type are shortened.*

Word type	Example
Determiners	each (mỗi, từng), every (mọi), one (cái), the (các, những, mấy),…
Adjunct	was (đã), will (sẽ), being (đang), just (vừa, mới), already (từng), done (xong, rồi), very (rất), slight (hơi), too (quá), be (là),…
Modal particle	ah (à, a), yeah (á, ạ, ấy, chứ, có, nhỉ, nhé, chứ, vậy, đâu), sure (chắc), maybe (chăng), huh (hả, hử)
Exclamation	yes (ơi, vâng, dạ), sir (bẩm, thưa), uh (ừ), omg (ôi, trời ơi), gosh (ô), eh (ủa), ouch (kìa, ái, ối), oh (than ôi, hỡi ôi, eo ôi, ôi giời ôi),…
Emphasis particle	all (cả), major (chính), target (đích), right (đúng), only (chỉ), these (những), come (đến), until (tận), now (ngay),...
Modal verbs	Should (nên), need (cần), must (phải), need (cần phải), can (có thể), get (bị, được, mắc phải), look (trông), hope (mong), wish (chúc, ước), pray (cầu), want (muốn), dare (dám), decide (định), bear (nỡ), well (thôi), let it be (đành)…
Formal prepositions	because (tại, bởi, vì), from (từ), though (tuy, dù), although (mặc dầu), if (nếu),..

Rule 2: Change order Noun - word count

Table 2. *Order of changing noun structure - word count.*

	Vietnamese	Correct syntax in VSL
Structure	Count + noun	Noun + count
Example	Hai quả táo (Two apples)	Quả táo hai Apples two

Rule 3: Change the order of Verbs - Negative words

Table 3. *Order of changing Verbs - Negative words.*

	Vietnamese	Correct syntax in VSL
Structure	Negative word + verb	Verb + negative word
Example	Tôi không ăn (I don't eat)	Tôi ăn không (I eat don't)

Rule 4: Change the order of complement – verbs

Table 4. *Order of changing complement – verbs.*

	Vietnamese	Correct syntax in VSL
Structure	Subject + verb + complement	Subject + complement + verb
Example	Cô ấy ăn táo (She eats apples)	Cô ấy táo ăn (She apples eats)

Rule 5: Change the word order in the interrogative sentence

Table 5. *Change the word order in the interrogative sentence.*

	Vietnamese	Correct syntax in VSL
Structure	Subject (question word) + predicate + complement?	Predicate + complement + subject (question word)?
Example	Ai ăn táo? (Who eats apples?)	Táo ăn ai? (apples eats Who?)

	Vietnamese	Correct syntax in VSL
Structure	Subject + predicate + question word + complement?	Subject + complement + predicate + question word
Example	Cường ăn mấy quả táo? (Cuong eats how many apples?)	Cường táo ăn mấy? (Cuong apples eats how many?)

2.3. The Issue of Extracting and Parsing Rules

The objective of rule-based translation is to perform the following steps: parse the source text, generate an intermediate symbolic representation, and then produce the final translation in the target language. For our specific problem, we utilized the parsing toolkit developed by Nguyen et al. [22]. Preprocessing involves normalizing the input data and employing a set of techniques to extract and label VietWS terms. These methods are used to derive rules from the bilingual sentence pair data between Vietnamese and Vietnamese Sign Language (VSL). The process of constructing bilingual data follows the steps outlined below:

Step 1: Crawl VSL dictionary from the source: https://tudienngonngukyhieu.com/. This dictionary contains sign language commonly used by the deaf population in Vietnam.

Step 2: Expand the VSL Sign Language Dictionary: Since 2017, we have been compiling a database of VSL dictionaries from the aforementioned website in collaboration with professionals and the deaf community. Due to sign language's brevity and simplicity, its lexicon has a limited selection of words. We gathered a total of 3053 language units. As of 2022, the number of words and phrases has continuously increased, and there are now 6304 characters/words/phrases represented in sign language.

Step 3: Create a list of synonyms: This step aims to optimize the representation of words and phrases from Vietnamese sentences into VSL, given the limited availability of the sign language dictionary. Words not represented in sign language, including proper names and numerals, can be communicated in VSL through spelling.

Step 4: Generate a set of "bilingual" sentence pairs: The data consists of communication-related phrases that have undergone partial semi-automatic processing and then meticulous examination. Finally, the data were reevaluated by several sign language specialists.

In the end, for the creation of a rule-based translation system, we accumulated a total of 10,000 pairs of Vietnamese-to-VSL bilingual phrases in the communication domain, which was chosen for its practical utility for the deaf community. The reference data can be found at https://github.com/BichDiep/data-rules-VSL. Rules are then extracted from the constructed data. The following table provides details of a selection of extracted rules.

Table 6. *Selection of extracted rules.*

No	Parsed Vietnamese sentences	Grammar rules	Parsed Sign Language Sentences	Extracted Rules
1	((SQ (NP (N Bạn) (N tên)) (VP (V là) (WHNP (P gì))) (? ?)))	1	SQ (NP (N Bạn) (N tên) (P gì)) (? ?)	SQ (NP (N) (N)) (VP (V) (WHNP (P)) → SQ (NP (N) (N) (P))
2	S (NP (P Tôi)) (NP (N tên)) (VP (V là) (NP (Np Hiếu))) (..)	1	S (NP (P Tôi)) (NP (N tên) (Np Hiếu)) (..)	S (NP (P)) (NP (N)) (VP (V) (NP (Np)) → S (NP (P)) (NP (N) (Np))
3	S (NP (N Khế)) (C thì) (AP (A chua)) (..)	1	S (NP (N Khế)) (AP (A chua)) (..)	S (NP (N)) (C) (AP (A)) → S (NP (N)) (AP (A))
4	S (NP (N Mít)) (C thì) (AP (A ngọt)) (..)	1	S (NP (N Mít)) (AP (A ngọt)) (..)	
5	S (NP (P Tôi)) (NP (M 19) (N tuổi)) (..)	2	S (NP (P Tôi)) (NP (N tuổi) (M 19)) (..)	S (NP (P)) (NP (M) (N))) → S (NP (P)) (NP (N) (M))
6	((S (NP (P tôi)) (VP (R không) (V đi)) (..)))	3	((S (NP (P tôi)) (VP (V đi) (R không)) (..)))	((S (NP (P)) (VP (R) (V)) (..))) → ((S (NP (P)) (VP (V) (R)) (..)))
8	((S (NP (P tôi)) (VP (R không) (V chơi)) (..)))	3	((S (NP (P tôi)) (VP (V chơi) (R không)) (..)))	
9	S (NP (P Tôi)) (VP (V thích) (NP (N mèo))) (..)	4	S (NP (P Tôi)) (VP (N mèo) (V thích)) (..)	S (NP (P)) (VP (V) (NP (N)) → S (NP (P)) (VP (N) (V))
10	SQ (NP (P Ai)) (VP (V biết) (VP (V bơi))) (? ?)	5	SQ (VP (V Biết) (VP (V bơi) (NP (P ai)))) (? ?)	SQ (NP (P)) (VP (V) (VP (V))) → SQ (VP (V) (VP (V) (NP (P))))
11	S (NP (P Tôi)) (VP (R không) (V thích) (NP (N rắn))) (..)	3 and 4	S (NP (P tôi)) (A rắn) (V thích) (R không)) (..)	S (NP (P)) (VP (R) (V) (NP (N)) → S (NP (P)) (A) (V) (R))
12	SQ (NP (M Một) (N năm)) (VP (V có) (NP (L mấy) (N mùa))) (? ?)	1 and 5	SQ (NP (M Một) (N năm) (N mùa) (L mấy)) (? ?)	
13	SQ (NP (M Một) (N tuần)) (VP (V có) (NP (L mấy) (N ngày))) (? ?)	1 and 5	SQ (NP (M Một) (N tuần) (N ngày) (L mấy)) (? ?)	SQ (NP (M) (N)) (VP (V) (NP (L) (N))→ SQ (NP (M) (N) (N) (L))
14	SQ (NP (M Một) (N năm)) (VP (V có) (NP (L mấy) (N tháng))) (? ?)	1 and 5	SQ (NP (M Một) (N năm) (N tháng) (L mấy))) (? ?)	
	…	…	…	…

2.4. Rule-Based Translation System

We will develop a rule-based translation system following these steps. The system involves the word separation preprocessing phase from the original database preprocessing and the input sentence preprocessing stage of the translation system. We parse the initial data, which includes the constructed pairs of words, using the Vietnamese parsing tool. By incorporating the synonym data from the Vietnamese Sign Language dictionary, we synthesize the rules to create the rule-based translation system. When translating a Vietnamese sentence, we analyze the sentence and match it against the rules. If a corresponding rule is found, the input sentence is processed through the rule translation system, producing a syntactically correct sentence in sign language. In cases where a rule is not found, the translated sentence is saved and added to the waiting database. This database then generates new rules to be added to the subsequent rule set. The process of building the system and performing rule-based translation is illustrated in Figure 3.

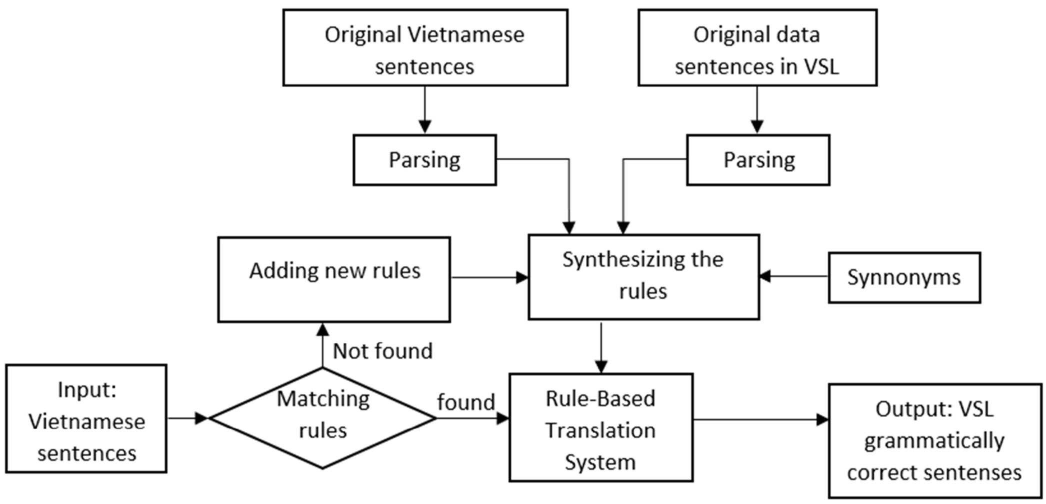

Figure 3. *Rule-based translation system.*

Algorithm of the rule-based translation system is as follows:

Algorithm: Rule-based-MT-VSL
Input: Sentence S in Vietnamese,
Output: Sentence S' in the syntax of VSL.
1. R is set of syntax conversion rules
2. WD = ∅; (WD: Waiting Dataset)
3. SYN is Synonyms files with n line: SYN[n,1] in VSL dictiary; SYN[n, i] is a synonym of SYN[n,1]; (i=1: m).
4. Si ⇐ Tokenization (S)
5. While ∃ Si in SYN:
Si = SYN[n,1]
6. (TS, PS)⇐ Parsing (S)
7. If (Find Ps in R)
ST= Transform (TS)
Else
Add S to WD
8. S'= Shorten (ST)
9. Return S'

3. Experiment and Evaluate the Results

To assess the effectiveness of the rule-based translation method for the Vietnamese-VSL translation problem, we conducted an analysis using BLEU-scored test sets. The bilingual evaluation understudy (BLEU) was initially proposed by IBM in 2002 and has since become the standard assessment metric for machine translation studies [23]. In these experiments, we evaluate the translation performance based on the BLEU score, following the Multi-BLEU instructions.

To ensure a comprehensive evaluation of the translation method we employed, we supplemented the dataset in the domain of typical communication phrases with data from other domains, including literature, engineering, and medical. This augmentation was done to provide a thorough assessment test set, allowing us to evaluate the translation system's performance across various domains. By including diverse content from different domains, we aim to capture a wide range of translation challenges and assess the system's adaptability and accuracy in handling varied linguistic contexts.

The first dataset comprises sentences categorized as popular communication sentences. We chose this domain for data construction because it closely aligns with the most accessible and widely used domain for hearing-impaired individuals to access information. Additionally, this domain is considered crucial and valuable for addressing translation challenges.

The rule-based translation system performs exceptionally well in this domain, achieving a very high BLEU score compared to other bilingual pairings. This can be attributed to the fact that a majority of the sentences in the communication sentence dataset are relatively simple, and the proportion of terms present in the sign language dictionary is higher compared to other categories. As a result, the translation system excels in accurately handling these frequently occurring basic sentences, contributing to its superior performance in this particular domain.

The sentences in the medical domain were randomly selected from the website of a well-known hospital in Vietnam due to their relevance to the medical sector. Many medical terminologies are not currently present in the existing VSL dictionary. In line with the rule-based machine translation system that we have developed, these words remain unchanged and are represented as word-for-word spellings to ensure comprehension for hearing-impaired individuals. However, when sign language professionals manually translate these sentences, these medical terms will be transformed into synonyms or near-meaning signs using the available VSL vocabulary, making them more easily understandable for the hearing-impaired audience. This adaptation allows for better communication and comprehension in the medical domain, ensuring that crucial medical information is accessible and well-understood by the deaf and hard-of-hearing community.

Table 7. *BLEU score of Vie-VSL translation from the medical domain.*

Original sentence	Machine translation	Translated by VSL experts	BLEU Score			
			1-gram	2-gram	3-gram	4-gram
Điều trị bệnh van động mạch chủ với kỹ thuật mổ tim mở ít xâm lấn. (Treatment of aortic valve disease with minimally invasive open-heart surgery.)	Điều trị bệnh van động mạch chủ với kỹ thuật mổ tim mở ít xâm lấn. (Treatment of aortic valve disease with minimally invasive open-heart surgery.)	Điều trị bệnh cửa mạch máu kỹ thuật mổ tim mở ít can thiệp bên trong. (Treatment of portal vascular disease with open heart surgery with minimal internal intervention)	62.5	46.67	35.71	23.08
Bệnh tim có nguy cơ cao, suy tim rất nặng. (Heart disease has a high risk, severe heart failure.)	Bệnh tim có nguy cơ cao, suy tim rất nặng. (Heart disease has a high risk, severe heart failure.)	Bệnh tim nguy cơ cao, giảm hoạt động tim nặng. (Heart disease has a high risk, severe reduction in cardiac activity)	70	55.56	37.5	28.57
Bệnh nhân bị béo phì (Patient is obese)	Bệnh nhân bị béo phì (Patient is obese)	Bệnh nhân béo nhiều. (Patient very fat)	75.00	66.67	50.00	0

Based on the assessment sets that we have assembled, the translation value (BLEU score) for various data sets in the automatic Vie-VSL translation is as follows:

Table 8. *BLEU score for different datasets.*

Data sets	Number of sentences in test set	BLEU Score
Data set 1: Domain of sentences in communication	150	81.15
Data set 2: Domain of sentences in literature	150	48.68
Data set 3: Domain of sentences in engineering	150	64.13
Data set 4: Domain of sentences in medicine	150	56.24
Average		62.55

Figure 4 depicts a comparison of BLEU scores across different domains. BLEU1 values represent the average BLEU score for sentences with fewer than three words, BLEU2 values represent the average BLEU score for sentences with four words, BLEU3 values represent the average BLEU score for sentences with five words, and BLEU4 values represent the average BLEU score for sentences with more than five words.

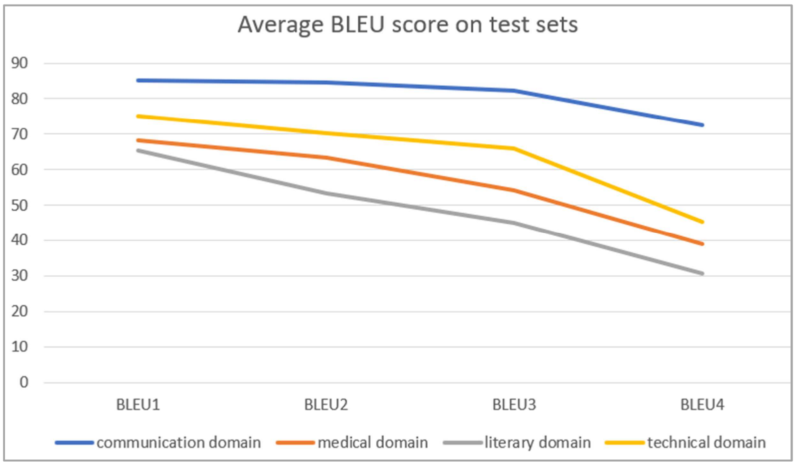

Figure 4. *Average BLEU score across test sets.*

In general, the BLEU scores on the test sets are higher compared to certain other language pairs, including our case. The translation paradigm remains mostly unchanged since the majority of linguistic units in both languages have equivalent representations. Only a few non-sign language terms are substituted with synonyms to adapt to the sign language context. Regarding sentence structure, VSL pairings exhibit significantly less diversity compared to other language pairs. As a result, the language model used for VSL translation is simpler, benefiting from the convergence of the probabilistic model. However, there are still variations observed between test sets. These variations largely depend on the length, complexity, and vocabulary of each domain's sentences. For instance, the communication domain mostly comprises short and simple sentences, and the proportion of vocabulary from the VSL lexicon is higher compared to other domains. These factors contribute to the higher BLEU scores for the communication domain.

4. Conclusion

VSL is considered a low-resource language, and while research on machine translation for other low-resource languages has shown some successes, the field of machine translation for VSL remains open with multiple possible solutions. Current research indicates that rule-based translation generally yields inferior outcomes compared to statistical machine translation techniques. However, for our specific problem, which demands a small MT system and limited resources, the rule-based approach is still suitable.

Among rule-based translation strategies, both direct machine translation and interlingual machine translation are not suitable for our problem. Instead, we adopt transfer machine translation, which involves two levels: syntactic conversion and semantic conversion. This process entails transferring linguistic knowledge, such as words, syntax, methods, meaning, and usage, from the source language to the target language using a set of rules.

The evaluation results demonstrate that the BLEU scores in our test sets are significantly higher compared to other bilingual translation problems. This is primarily due to the nature of our problem, where the translation model mostly consists of identical language units in both languages. As a result, we apply this proposed technique to address the VSL machine translation issue, which holds scientific and practical significance.

Conflicts of Interest

The authors have no conflict of interest to declare.

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