

Sign Language Writing System: Focus on the Representation of Sign Language-Specific Features

Nobuko Kato, Yuito Nameta, Yuhki Shiraishi
 Faculty of Industrial Technology
 Tsukuba University of Technology
 Tsukuba, Japan
 e-mail: {nobuko, yuhkis}@a.tsukuba-tech.ac.jp

Akihisa Shitara
 Graduate School of Library, Information and Media Studies
 University of Tsukuba
 Tsukuba, Japan
 e-mail: theta-akihisa@digitalnature.slis.tsukuba.ac.jp

Abstract—Achieving universal access in professional settings necessitates the development of computer-assisted input/output systems tailored to sign language, considering the perceptual characteristics of the deaf and hard of hearing individuals. This study examines sign language-specific features to elucidate the requirements for a sign language writing support system. Analysis of news sentences expressed in sign language reveals the prevalence of distinct expressions like topicalized and wh-cleft sentences. We explore a writing system that incorporates these features and conduct experiments involving transcribing sign language movies. The paper delineates the crucial features of sign language sentences for effective writing and outlines the requisite functions of the system based on actual writing experiments.

Keywords—deaf and hard of hearing; sign language; visual language; sign writing; communication support.

I. INTRODUCTION

The enrollment of individuals with disabilities in higher education institutions and the emphasis on lifelong learning are increasing, necessitating expanded learning opportunities tailored to individual disabilities. In specialized educational settings like higher education, it is necessary to ensure effective information and communication methods aligned with the unique characteristics of each disability.

Various services are employed to facilitate communication for individuals who are Deaf and Hard of Hearing (DHH) in higher education institutions, including real-time captioning by transcriptionists, Automatic Speech Recognition (ASR), sign language interpretation, and notetaking. ASR technology is increasingly explored to automatically generate caption text for DHH users [1]. However, it is crucial to recognize that DHH individuals are bicultural and have the right to be educated in their native sign language [2]. Quality education delivered in national sign languages and national written languages is one of the key factors for fulfilling the education of deaf children and adult learners [3].

Some countries use sign language a method of expressing sign language words in the word order of spoken language, but it can be difficult for deaf people to understand [4]. Research on sign language interpreting in universities has indicated that it is important for deaf students to receive information using the correct sign language structure [5]. Also, written languages is pivotal for the academic success of

deaf children and adult learners [3]. While some countries utilize sign language with word orders mirroring spoken language, it can pose comprehension challenges for deaf individuals [4]. Studies on sign language interpreting in universities highlight the significance of instructors' clear use of sign language, as perceived by deaf students [6]. Consequently, there is an anticipated rise in opportunities for specialized content learning facilitated by interpreters or direct sign language instruction in various countries.

Writing presents a significant challenge in sign language learning. Existing writing systems for spoken language (Figure 1d), are ill-suited for sign language, which constitutes a distinct language. Unlike hearing individuals who can write while listening (Figure 1a), deaf individuals must write while simultaneously watching sign language (Figure 1b).

Therefore, the development of a computer-based support system for writing sign language is essential to streamline the writing process and allocate more time for the comprehension of specialized content. To achieve this, it is imperative to delineate the functions such a system should encompass based on sign language characteristics.

This study aims to address the following research questions:

- RQ1:** What are the sign language-specific features crucial for writing specialized sign language content?
- RQ2:** How can sign language sentences be written while preserving sign language-specific expressions?

The remainder of this paper is structured as follows: Section II provides insights into sign languages and relevant prior research. Section III outlines the characteristics of signed sentences and presents the proposed method based on these characteristics. Section IV elaborates on the experimental methodology and results, while Section V discusses the findings based on the experimental results. Finally, Section VI presents a summary of the study.

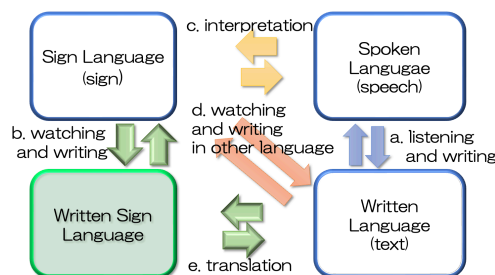


Figure 1. The relationship between spoken and written language.

II. SIGN LANGUAGE NOTATION METHODS

A. Sign Language

Sign Language serves as a visual language used by the deaf community, where linguistic information is communicated not only through hand shapes and movements but also through non-manual markers such as facial expressions, gaze, and head movements [4].

Unlike spoken languages like Japanese, which are linear and rely on speech, sign languages are intricate, employing hand gestures, facial expressions, body movements, and spatial elements [4]. Thus, devising a writing system for sign languages demands innovative approaches distinct from those used for spoken languages.

B. Related Works

Efforts to transcribe sign languages into writing have taken two main approaches: iconographic and alphabetic (using letters from existing spoken languages) [7].

Iconographic methods entail symbolizing hand actions and describing words and sentences, offering the advantage of representing novel words and actions but often result in a high number of descriptions per word, primarily suited for analysis [8][9]. Notational systems like Si5S and ASLwrite prioritize writing but use specialized fonts for sign language, which makes it difficult for learners to correlate these systems with existing spoken language texts.

ASL-Gloss, another method, employs characters from existing spoken languages, using English words as labels to describe American Sign Language (ASL). This system follows ASL’s word order and grammatical rules, with glosses used for teaching sign language and grammar [10]. Few studies have examined the use of ASL-gloss in actual educational settings, and examples that have examined the use of ASL-gloss as a potential method for improving reading and comprehension skills in people with severe hearing loss have not supported ASL-gloss as an effective method for improving comprehension [11].

An example of using Japanese as a label is when it is used as an intermediate language for machine translation between Japanese and Japanese Sign Language [12].

In university settings, where comprehension hinges on understanding key spoken words, it is crucial for deaf students to receive information in semantically and syntactically correct sign language structure [5].

Therefore, our study adopts existing characters to describe terms and explores a method for diagrammatically representing the structure of sign language, aiming to address these challenges.

III. SIGN LANGUAGE FEATURES AND PROPOSED METHOD

A. Analysis of News Texts

To address RQ1, an analysis was conducted to explore sign language-specific expressions in texts containing specialized content. Owing to limited material of signed sentences expressing specialized content, sign language news was chosen for analysis. News sentences typically employ

topic-specific vocabulary and present factual information in a logical manner.

We analyzed 44 sentences from Sign Language News, presented by four deaf news anchors at the Japan Broadcasting Corporation.

Table 1 showcases examples of non-manual markers observed during the analysis. Topicalized sentences introduce the topic at the outset, while Wh-cleft sentences feature a question word in the middle.

B. Results of the Analysis of Signed Language Sentences

The analysis of signed sentences in Sign Language News yielded the following insights:

- Complex sentences were prevalent in sign language news texts (32 out of 44 sentences).
- Presenting the topic at the beginning of the sentence was frequently used (34 out of 44 sentences).
- Topicisation, wh-cleft sentences, and reason-for sentences were used to introduce the topic.

Although Japanese sentences lacked topics, sign language sentences frequently presented topics using sign language-specific expressions, such as topicalisation/wh-cleft sentences or reason-for sentences explicitly stating the reason at the sentence’s onset.

Thus, presenting the topic at the beginning of a sentence emerges as a sign language-specific feature crucial for facilitating comprehension by DHH individuals.

C. Proposed Method

To address RQ2, we propose a new writing system that incorporates the identified sign language-specific features.

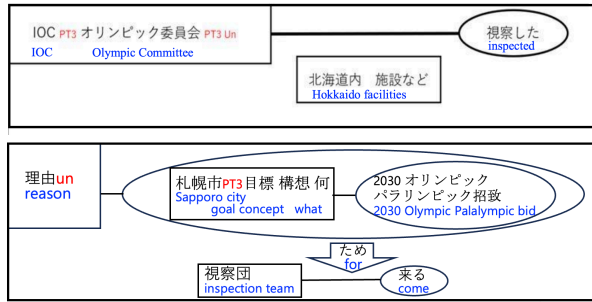
Previously, we proposed a method to represent the spatial structure of sign language on a two-dimensional plane using symbols, such as spatial representation of subject and object [13]. This time, we focus on the macroscopic structure of sign sentences, aiming to highlight and visualize the topic in a manner conducive to DHH comprehension.

Furthermore, in specialized contexts, it is essential to accurately understand technical terminology in the spoken language. Hence, spoken language text is used as labels for sign words. Figure 2(a) illustrates an example of a topicalized sentence using Proposal A.

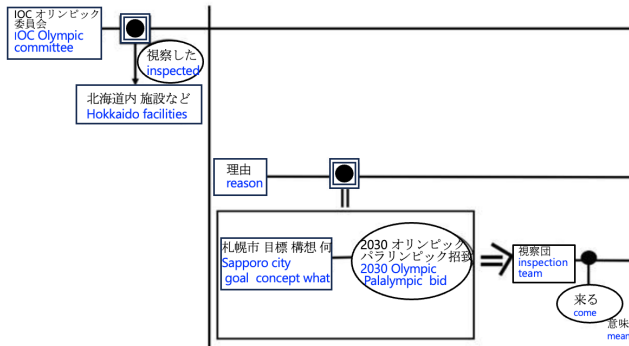
The sentence is enclosed in an outer-frame rectangle, with squares and circles representing subjects, objects, and predicates. The rectangle in the top left-hand corner denotes the topic (Figure 2(a)).

TABLE I. NON-MANUAL MARKERS OF SIGNS USED IN THE ANALYSIS

Sentence type	Non-manual markers
Topicalization	Eyebrows raised and eyes widened in the topic area at the beginning of the sentence
Wh-cleft sentence	Squinting and slightly shaking the head in the middle of a sentence
Causal relationship	Eyebrow raised and head forward and fixed in the part of the condition
Complex sentence	Nodding motion before and after the clause



(a) Proposa A



(b) Proposal B

Translation in English: The IOC Olympic member inspected facilities in Hokkaido. Because Sapporo City is aiming to bid for the 2030 Olympic and Paralympic Games.

Figure 2. Examples of a topicalization sentence and example of a reason sentence (Blue letters indicate translated English).

In Proposal B, which employs a single line to preserve the word's position in sign space across consecutive sentences, the branching point is surrounded by a double square to signify that the subject is the topic (Figure 2(b)).

IV. EXPERIMENT

A. Experimental Method

We conducted an experiment to test the efficacy of the proposed sign language writing methods, specifically based on Proposals A and B.

The participants comprised 12 university students who were either deaf or hard of hearing. Initially, the participants were briefed on the rules of the writing systems and engaged in practice sessions to familiarized themselves with reading written signs using the proposed methods.

During the experiment, participants were presented with a choice between Proposal A and Proposal B, based on their preference for ease of understanding. They were then shown a video featuring a sign language news program, where the first and second sentences were accompanied by a ticker displaying only the main points. The third sentence was presented solely in sign language, without any ticker. Participants were instructed to transcribe the third sentence using their chosen writing method.

This setup aimed to simulate scenarios commonly encountered in academic settings, where signs are often displayed alongside textual materials, such as slides, allowing students to simultaneously view both sign language and written or spoken language, such as English or Japanese.

Ethical approval for this study was obtained from the Research Ethics Review of Tsukuba University of Technology, where the experiment was conducted.

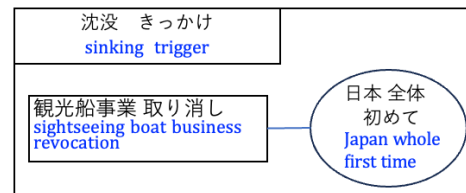
B. Experimental Results

In the sign language news watching and writing experiment, 10 out of 12 participants opted for Proposal A, while two participants preferred Proposal B.

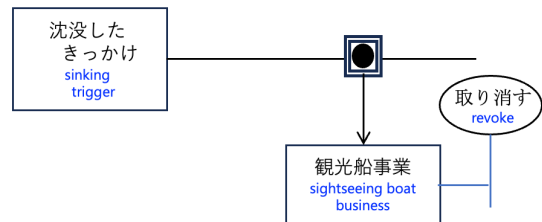
In response to the topicalized sentence, 7 out of 10 participants who chose Proposal A accurately reflected the topic using the proposed method.

Although there were multiple possible labels for a single sign word, 11 out of 12 participants opted for a technical term as their label choice. However, errors in symbol selection and placement were observed, presumably owing to misinterpretation of sign language or the influence of the preceding context.

Figure 3 illustrates examples of the participants' writing. In Figure 3(a), "the sinking trigger" is correctly selected as the topic, with the proposed symbol correctly employed. Conversely, Figure 3(b) depicts correct topic selection but errors in placement of symbols were observed. It is inferred that the participant placed the topic in the subject position, possibly owing to its placement at the beginning of the sentence.



(a) Example 1 using Proposal A.



(b) Example 2 using Proposal B.

Translation in English: This is the first time in the nation that a tourist boat business license has been revoked as a result of an accident. A list of sign labels: {sinking} {trigger} PT3 {sightseeing} {boat} {business} {revocation} PT3 {Japan} {whole} {first time}

Figure 3. Examples of participants writing from a sign language video using the proposed method (Reproduced from handwritten experimental results. Blue letters indicate translated English.).

V. DISCUSSION

A. RQ1: Sign Language-Specific Features

Comparison between Japanese and signed news sentences revealed the following features:

- Complex sentences were often used, with over 70% exhibiting complexity, contrary to the common belief of sign sentences being short and simple. and many sentences presented a topic at the beginning of the sentence.
- The structuring of complex sentences in sign language often involves presenting the topic at the sentence's outset.

Sign language employs specific expressions like topicalization and wh-cleft to introduce and emphasize topics. For instance, in sentences indicating reasons, sign language presents the word "reason" at the beginning, followed by the logical marker "for," and conclude with a phrase expressing the result, a structure not mirrored in Japanese (Figure 2(a)).

These specific expressions are considered to serve as aids in conveying technical concepts in a digestible manner for DHH individuals.

B. RQ2: Writing Sign Language Sentences

Developing a writing system for sign language necessitates considering the characteristics of DHH individual's perceptual characteristics and information processing. Therefore, such a system must incorporate spatial representation, time-series depiction, and visualization of grammatical and logical structures.

We propose a method that projects spatial and time-series representations onto a 2D plane and uses symbols to represent grammatical and logical structures. In addition to the basic spatio-temporal representation, our approach focuses on the macroscopic structure of sentences, represented by Non-Manual Markers (NMMs) and other visual cues.

The experimental preference for Proposal A by 10 out of 12 participants underscores that the method of emphasizing the topic at the beginning is effective. Topic sentences are represented by NMMs such as raised eyebrows (Table 1). While NMMs are said to be challenging for learners to master, written signed sentences could aid in comprehending these expressions.

Regarding sign labels, 11 out of 12 participants used technical terms in real-time sign writing. In order to use technical terms as a label, we need to consider how the sign language and slides are presented.

In this experiment, the participants did not necessarily consider the structure of the whole sentence before writing the sentence but tended to record the sign labels in the order of time series. Although the basic word order in Japanese Sign Language is typically SOV (Subject-Object-Verb), word order can be changed to present a topic, and the first position in a sentence does not always indicate the subject. Moreover, in Japanese Sign Language, there are homonyms between nouns and verbs, making it difficult to distinguish between similar signs (for example, 'revoke' as a verb versus 'revocation' as a noun). The experiment revealed difficulties

in selecting and positioning symbols (i.e., Figure 3(b)), highlighting the need for computer support, such as automatic placement and insertion of symbols.

C. Limitation

This study's limitations include the small number of participants in the experiment, variability in sign language proficiency, and the limited number of signed sentences. Further research with a large number of expressions and sentence patterns is needed to design a system that is useful for improving the learning performance of DHH people.

VI. CONCLUSION

This study aimed to develop a computer-assisted writing system tailored to the perceptual characteristics of DHH individuals, considering the visual and spatial nature of sign language and the unique characteristics of signed text. By analyzing news sentences expressed in sign language, we confirmed that numerous expressions specific to sign language are used, such as topicalized and wh-cleft sentences. To establish a new way of expression that is intuitive and understandable for the deaf, we proposed a writing system that reflects these features and conducted an experiment in which participants wrote a sign language video.

The results of the experiment demonstrate that by using the proposed method, participants could actually write signed sentences with sign language-specific features.

In the future, we intend to expand our research by conducting a broader survey involving a larger sample of sentences. This will enable us to further refine our proposed writing system and provide support for communication and learning for the DHH people.

ACKNOWLEDGMENT

This study was supported by JSPS KAKENHI (Grant number 22K02999, 19K11411). We would like to thank Editage for editing and reviewing this manuscript for English language.

REFERENCES

- [1] L. Berke, S. Kafle, and M. Huenerfauth, "Methods for evaluation of imperfect captioning tools by deaf or hard-of-hearing users at different reading literacy levels," *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, ACM, Apr. 2018, pp. 1–12. doi: 10.1145/3173574.3173665.
- [2] K. R. Miller, "American Sign Language: Acceptance at the university level," *Language, Culture and Curriculum*, vol. 21, no. 3, pp. 226–234, Nov. 2008, doi: 10.1080/07908310802385899.
- [3] WFD, "7 September 2016: WFD Position Paper on the Language Rights of Deaf Children," [Online]. Available from: <http://wfdeaf.org/news/resources/wfd-position-paper-on-the-language-rights-of-deaf-children-7-september-2016/> [retrieved: 4, 2024]
- [4] M. Huenerfauth and V. Hanson, "Sign language in the interface: access for deaf signers," in *The Universal Access Handbook*, CRC Press, pp. 1–18, 2009. doi: 10.1201/9781420064995-c38.
- [5] J. Napier, "University Interpreting: Linguistic Issues for Consideration," *Journal of Deaf Studies and Deaf Education*,

- vol. 7, no. 4, pp. 281–301, Oct. 2002, doi: 10.1093/deafed/7.4.281.
- [6] H. G. Lang et.al., “A study of technical signs in science: implications for lexical database development,” *Journal of Deaf Studies and Deaf Education*, vol. 12, no. 1, pp. 65–79, Aug. 2006, doi: 10.1093/deafed/enl018.
- [7] D. A. Grushkin, “Writing Signed Languages: What For? What Form?,” *American Annals of the Deaf*, vol. 161, no. 5, pp. 509–527, 2017, doi: 10.1353/aad.2017.0001.
- [8] T. Hanke, “HamNoSys – Representing sign language data in language resources and language processing contexts,” *Proceedings of the 1st Workshop on the Representation and Processing of Sign Language*, 2004, pp. 1-6.
- [9] H. Van Der Hulst and R. Channon, “Notation systems,” in *Sign Languages*, 1st ed., D. Brentari, Ed., Cambridge University Press, pp. 151–172, 2010, doi: 10.1017/CBO9780511712203.009.
- [10] C. Valli and C. Lucas, *Linguistics of American Sign Language: an introduction*, 3rd ed. Washington, D.C: Gallaudet University Press, 2000.
- [11] E. Rathkey, “Can ASL-gloss be used as an instructional tool to teach written English to the deaf?,” *Open Access Dissertations*, paper 835, Jan. 2019, doi: 10.23860/diss-rathkey-emma-2019.
- [12] K. Yano and A. Utsumi, “Pipeline signed Japanese translation using PBSMT and transformer in a low-resource setting,” *Journal of Natural Language Processing*, vol. 30, no. 1, pp. 30–62, 2023, doi: 10.5715/jnlp.30.30.
- [13] N. Kato, Y. Hotta, A. Shitara, and Y. Shiraishi, “Visually-structured written notation based on sign language for the deaf and hard-of-hearing,” *Proceedings of the 15th International Conference on Computer Supported Education - Volume 2: CSEDU, INSTICC, SciTePress*, 2023, pp. 543–549. doi: 10.5220/0011988700003470.