Enhancing Education for Deaf People: A Systematic Review of NLP Strategies for Automatic Translation From Portuguese to Brazilian Sign Language

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***Abstract*—This research-to-practice full paper presents a comprehensive and objective account of a study that collates, analyses, and synthesizes all available evidence on a specific research question. In light of the growing demand for inclusive solutions for the deaf community, driven by the impact of the global pandemic, technologies such as Speech-to-Text (STT) and Natural Language Processing (NLP) assume a pivotal role in promoting accessibility and effective communication. A systematic literature review was conducted to analyze tools that utilize natural language processing (NLP) and speech-to-text (STT) to translate Portuguese into Brazilian Sign Language (Libras) and evaluate their effectiveness. Some tools were identified, including OpenSigns, Hand Talk, and Virtual Sign, each of which exhibited certain limitations and challenges. To evaluate the quality of the translations, metrics such as Bilingual Evaluation Understudy (BLEU) score, Word Error Rate (WER), and Character Error Rate (CER) were employed. Furthermore, the potential of the Transformer and LightConv models as promising avenues for enhancing the efficiency and accuracy of translations was underscored. Nevertheless, considerable challenges persist, including the adaptation of cultural and grammatical nuances and the expansion of the character vocabulary to elevate translation quality.**

***Index Terms*—deafness; accessibility; assistive technology; natural language processing.**

I. Introduction

With approximately 430 million people with hearing loss worldwide, understanding and meeting their communication needs is critical [1]. As indicated by the World Health Organization, by 2024, approximately 5% of the global population will require rehabilitation services due to disabling hearing loss. Projections suggest that by 2050, 700 million individuals (or 1 in 10 of the global population) will be affected [1]. This condition, defined as a loss of more than 35 decibels in the better hearing ear, increases with age - among those older than 60 years, over 25% are affected by disabling hearing loss. Moreover, nearly 80% of people with disabling hearing loss live in low- and middle-income countries [1].

The COVID-19 pandemic has increased the demand for inclusive solutions for deaf students, highlighting the importance of virtual translators for simultaneous interpretation from Portuguese to Libras (Brazilian Sign Language) [2],[3].

Technological advances have been crucial to the inclusion of the deaf community, facilitating communication and promoting interaction between deaf and hearing people [4],[5]. From advanced computer systems to Libras applications, technologies have opened up new opportunities for communication and access to information for deaf people [6].

Speech-to-Text (STT) is a process that converts spoken words into written text and plays a crucial role in speech comprehension [7]. The integration of Speech-to-Text (STT) technology with Artificial Intelligence (AI) is becoming increasingly essential for enhancing communication quality, particularly through advancements in transcription accuracy and speech synthesis [8].

Natural Language Processing (NLP) is a field of computer science that aims to extract richer representations and meanings from natural language texts [9]. NLP uses linguistic concepts and tackles complex challenges such as anaphora and ambiguity. In addition to considering text as a sequence of characters, it examines its hierarchical structure and performs tasks such as grammar correction, speech-to-text conversion,

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automatic translation, and sentiment/opinion analysis [9].

The integration of STT and NLP represents a significant step forward in promoting inclusion and accessibility for the deaf community. In this context, this study aimed to conduct a systematic review to analyze the technologies that use NLP and STT for translating Portuguese into Libras and to evaluate the effectiveness of the available tools.

The remainder of this paper is organized as follows. First, Section II details the methodology employed in this systematic review, outlining the research process, data collection, and analysis methods. Next, in Section III, we present the results, including an analysis of the identified tools and their effectiveness. Then, Section IV explores the challenges and advancements in the field, emphasizing our findings. Finally, Section V concludes the paper, summarizing the key insights and proposing directions for future research.

II. Methodology

In the systematic mapping process, the research was delineated by four fundamental stages that provided a comprehensive approach to achieving the proposed objectives [10].

First, the main research question and secondary questions were formulated, which served as the conceptual basis for the entire investigation. Table I presents the set of research questions that delineated the focus of interest and investigation of this study, organized into two levels: one main question and three secondary questions.

The main question addressed the main tools available for translating audio from Portuguese to Libras using NLP and STT. The secondary questions explored specific aspects related to: the limitations of automatic translation; the evaluations used to measure the quality of translation; the resources and dictionaries available to assist in the process of translating audio into Libras; and the comparative effectiveness of these tools.

TABLE I
Review Research Questions

Type	Research Questions	
Main	MQ	What are the main tools available for audio translation from Portuguese to Libras using NLP and Speech-to-text?
Secondary 1	SQ1	What are the existing limitations in automatic audio translation to Sign Language?
Secondary 2	SQ2	What evaluations are used to measure the quality of audio translation to Sign Language with NLP and STT?
Secondary 3	SQ3	What resources and dictionaries are available to assist in audio translation from Portuguese to Libras?
Secondary 4	SQ4	What is the comparative effectiveness of these tools in terms of accuracy, processing time, and accessibility for Libras users?

The second step was to carefully define the research method to be used. Based on the expected results, it was decided to perform a systematic literature review according to Galvão and Ricarte [11]. With the method clearly defined, the third step was to carefully select the studies to be included. The following databases were selected: SBC-OpenLib, IEEE Xplore, CAPES, Science Direct, ACM Digital Library, and Web of Science.

Finally, the fourth and final phase focused on data extraction to identify and document the essential research information. The search term used was ”accessibility AND deaf AND natural language processing”. Additionally, we define inclusion and exclusion criteria for selecting studies.

The inclusion criteria prioritized research articles on accessibility for the deaf community, focusing on technologies to enhance interaction and communication. In addition, publications on NLP and STT algorithms that address the application of these technologies in deafness, including specific applications in sign language, were considered.

The exclusion criteria aimed to ensure timeliness and full availability of publications, with a time range from 2014 to 2024 and excluding works that were not fully available. Establishing a 10-year date limit in a systematic literature review is important to ensure the relevance and timeliness of the research. It helps focus on recent advances and trends, providing a comprehensive understanding of the current state of the field while avoiding outdated information that may no longer be applicable.

After applying the criteria, the abstracts of the selected articles were read to identify papers that were consistent with the objectives of the study, taking into account the relevance of the topics covered. Thus, relevant articles were selected for full reading. The initial search yielded 292 articles, but after applying exclusion criteria, this number was reduced to 34. After reviewing the abstracts, 14 articles were selected for full reading and further study (see Figure 1 and Table II).

TABLE II
Articles Retrieved Using the Search String

Bases	Articles Retrieved	Filtered	Selected
ACM Digital Library	159	16	7
CAPES	9	3	3
IEEE Xplore	17	7	4
Science Direct	99	7	0
SBC-OpenLib	0	0	0
WEB of Science	8	1	0
Total	292	34	14

During the systematic literature review, two tools were used to manage and organize the articles found: Mendeley[1] and Research Rabbit[2]. Both are tools designed to streamline the researcher's workflow and provide robust resources for managing and exploring academic literature. They allow users to efficiently organize bibliographic references, simplifying the process of searching for and accessing relevant articles. In addition, both platforms serve as a way for researchers to discover new studies in their respective fields of interest.

However, there are notable differences between these two tools. Mendeley distinguishes itself by incorporating an aca-

[1] https://www.mendeley.com
[2] https://www.researchrabbit.ai

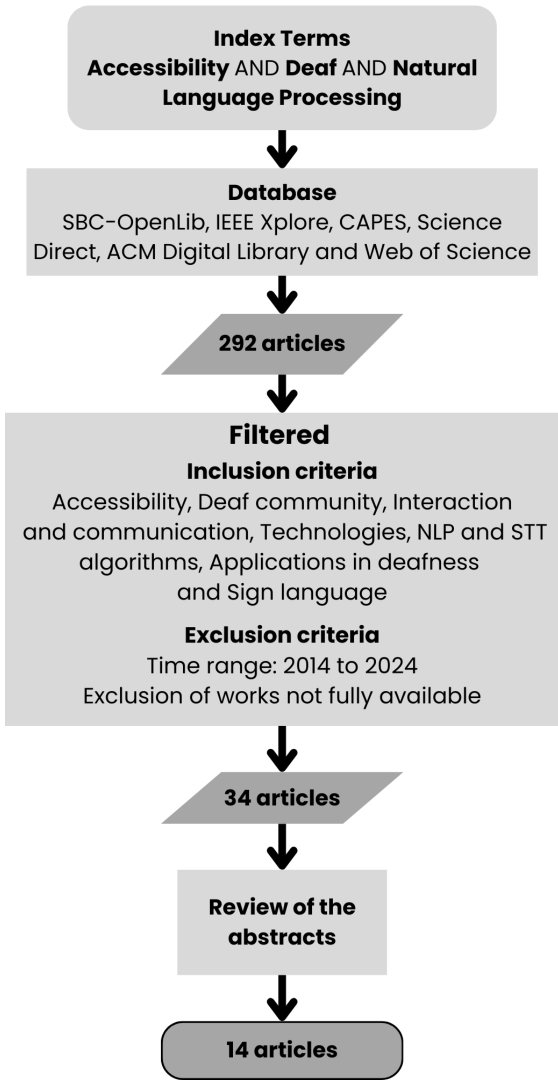

Fig. 1. Article selection procedure

demic social network that allows users to share libraries, collaborate on research, and connect with other scholars. In addition, Mendeley offers complementary features such as collaborative annotation and the creation of research groups.

In contrast, Research Rabbit has a more specialized focus on improving the discovery and organization of scholarly literature. It offers advanced search capabilities and visualization tools, including the ability to generate graphs that illustrate the interconnectedness of articles. While Mendeley excels at seamless integration with other academic platforms and software, Research Rabbit operates with a greater degree of autonomy in its functionality.

In essence, while both Mendeley and Research Rabbit share the common goal of supporting researchers in their scholarly pursuits, each represents a different approach to literature management and exploration, characterized by unique features and functionalities. The choice between them depends on the individual needs and preferences of researchers.

III. Results and Discussion

To obtain a comprehensive view of the articles selected for full reading, the online platform Research Rabbit was used. Figure 2, shows just one of the relationships between the articles. Of the 14 selected articles, only 2 were related to each other and both were written by the same author.

Figure 3 shows the chronology of the articles found in this study. We can also see that, from 2020 to 2024, the recurrence of articles related to deafness, accessibility, assistive technology and natural language processing decreased considerably compared to previous years, demonstrating a significant gap in studies and developments in this area.

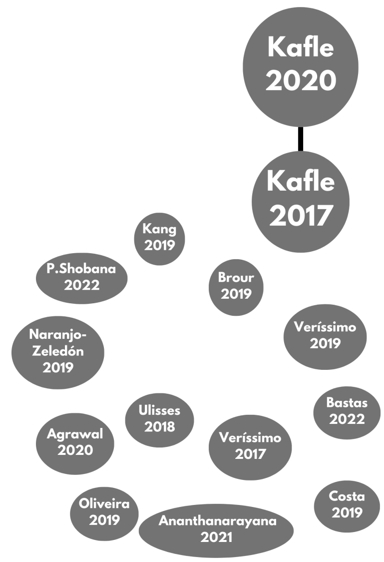

Fig. 2. Connection between the selected articles

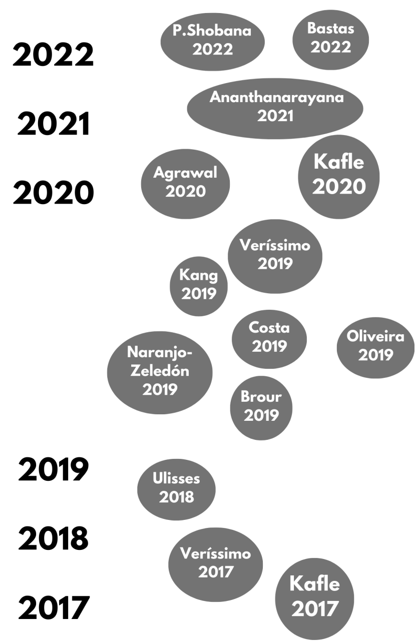

Fig. 3. Timeline

A. MQ - What are the main tools available for audio translation from Portuguese to Libras using NLP and Speech-to-text?

Several notable tools use Natural Language Processing (NLP) and Speech-to-Text technologies for audio translation from Portuguese to Libras (Brazilian Sign Language) (Table III). Among them, OpenSigns stands out. Developed by Costa et al [12], it builds on VLibras[3] to translate different languages into sign languages and, as an open source solution, allows for ongoing contributions to improve accuracy and adapt to different variations of Libras. Its goal is to improve accessibility and communication between people with different language backgrounds.

TABLE III
MAIN TOOLS AVAILABLE FOR AUDIO TRANSLATION FROM PORTUGUESE TO LIBRAS USING NLP AND SPEECH-TO-TEXT

Available Tools	Citations in articles
VLibras	2
Hand Talk	2
ProDeaf	1
Rybená	1
Virtual Sign	1
OpenSigns	1

Hand Talk[4] is another prominent tool in this area. It is an automatic Portuguese-to-Libras translation application that features a 3D animated agent named Hugo. In addition to its translation capabilities, Hand Talk provides an illustrated dictionary and instructional videos for learning Libras. Research by Rodrigues and Mill [6] highlights how Hand Talk enhances student autonomy, although it faces challenges such as vocabulary gaps.

The app also acknowledges the historical context of the deaf community in Brazil and uses technological resources to support education. However, problems remain, including translation errors during speech input, difficulties in recognizing tonal variations, and challenges with regional linguistic differences [13],[14].

Virtual Sign is another innovative platform that can display a 3D avatar performing the sign language of a specific country. It also allows input from a person signing in front of a camera and provides translations of written text [15]. This author also demonstrated that the recognition system with 5D gloves achieved accuracy rates of up to 86%, 78%, and 70% for datasets of 20, 50, and 100 words, respectively. Despite its advances, Virtual Sign faces challenges with grammatical rules for sign language and syntax for different languages. Further development is needed to improve the 3D avatar presentation, movement accuracy, and facial expressions.

Other tools highlighted by Costa et al. [12] include Signslator, SiMAX, Sign 4 Me, Hetah, ATLAS, and SASL-MT, each designed to facilitate better message comprehension for the deaf community.

[3]https://www.gov.br/governodigital/pt-br/acessibilidade-e-usuario/vlibras
[4]https://www.handtalk.me/en/

Table IV provides a comparative analysis of the main automatic translation tools for sign language identified in our systematic review. The technologies listed include VLibras, Hand Talk, and Rybená[5], each with different characteristics concerning different evaluation criteria. Among the aspects analyzed are simultaneous interpretation capability, presence of avatars for translation, free availability, translation quality, language support, and compatible platforms, which include web, mobile, and desktop applications.

TABLE IV
COMPARATIVE ANALYSIS OF AUTOMATIC TRANSLATION TOOLS FOR SIGN LANGUAGE

Available Tools	VLibras	Hand Talk	Rybená
Simultaneous Interpreting	No	Yes	Yes
Avatar Interpreters	Yes	Yes	Yes
Free	Yes	Mobile Only	No
Translation Quality	Good	Excellent	Fair
Language Support	pt-BR	English	pt-BR
Web	Yes	Yes	Yes
Mobile App	Yes	Yes	Yes
Desktop	Yes	No	Yes

Of the available tools, only Hand Talk and Rybená offer the capability of simultaneous interpretation, which is a crucial feature for effective real-time communication. Moreover, all tools employ avatars to facilitate translation, which can enhance the user experience through greater intuitiveness and visual appeal. In terms of cost, only VLibras is completely free, while Hand Talk is only free on mobile devices, and the other tools have limited access. The quality of translation is well-rated for the available tools. In essence, the selection of the optimal tool is contingent upon the user's particular requirements about the functional capabilities, linguistic assistance, and accessibility across diverse platforms.

B. SQ1 - What are the existing limitations in automatic audio translation to Sign Language?

The limitations in automatic audio translation to Sign Language in Portuguese are mainly related to concerns expressed by the deaf community (Table V). While criticisms often focus on the use of avatars to represent translations, the fundamental challenges lie in adapting content to Sign Language, considering its specific characteristics and grammar. This results in automatic translations that may not be fluent, culturally appropriate, or fully understood by deaf individuals [16].

Advancements made by automatic translators from spoken language to Sign Language face unresolved challenges, such as disambiguation, due to the complexity of Sign Languages, which vary by nationality and region [16]. The limitation of sign vocabulary for word representation is crucial. Compared to the vast set of words in natural language, the sign language vocabulary is considerably smaller, which can limit the expression of complex concepts [17].

[5]https://rybena.com.br

TABLE V
LIMITATIONS PRESENT IN THE ARTICLES

Current Limitations	Citations in articles
Linguistic corpus	4
Regionality	4
Sign Language Vocabulary	5
Audio Particularities,	2
Synchronization/Latency	1
Continuous speech recognition	1

One study highlights the importance of a broader vocabulary for model training, suggesting that including more signs would enhance the translation system’s capability [18]. Expanding the sign vocabulary and including more linguistic data are crucial to improving the efficiency of translation systems, and promoting more effective and inclusive communication for the deaf community.

Figure 4 presents a word cloud that elucidates the challenges associated with language and communication. It highlights pivotal terminology, including ”linguistic corpus”, ”sign language vocabulary”, and ”regionality”. ”Linguistic corpus” denotes a compilation of texts or language samples utilized for linguistic analysis. ”Sign language vocabulary”, in turn, pertains to the distinctive lexicon of sign language, encompassing signs, gestures, and expressions employed in sign language communication.

The term ”regionality” is used to describe the variations in communication that can be observed between different geographical regions. This is a particularly relevant concept in the context of sign languages, which often exhibit numerous regional variations. This figure provides an overview of the key challenges associated with translation and interpretation.

Fig. 4. Limitations in Audio Translation

Future research on automatic audio translation to sign language should prioritize the expansion of linguistic corpora and sign vocabulary, with a particular focus on Brazilian Sign Language (Libras). Addressing regional variations and improving synchronization and latency in real-time systems are essential areas for improvement. Enhancing continuous speech recognition tailored for sign language and ensuring cultural and contextual adaptation are also crucial. Leveraging emerging technologies like Transformer models and involving the deaf community in user-centric design will further refine translation accuracy and usability.

C. SQ2 - What evaluations are used to measure the quality of audio translation to Sign Language with NLP and STT?

Ananthanarayana et al [19] provided a comprehensive overview of the BLEU score, a metric developed in 2002 by Kishore Papineni and his team at IBM Research. This metric serves as a fundamental tool for evaluating automatically generated captions by comparing them to reference captions. By analyzing the n-grams of the predicted caption alongside those of the reference caption and incorporating unigram precision into its calculations, the BLEU score provides valuable insight into the quality of generated captions in various natural language processing applications [19].

Conversely, the Word Error Rate (WER) assesses transcription accuracy by comparing the ”hypothetical text” (system output) with the ”reference text”. While WER effectively quantifies recognition errors in the hypothetical text relative to the word length of the reference text, it overlooks nuances such as the relative importance of individual words or their significance to the overall message [20]. To address this limitation, Bastas et al [21] introduced the Character Error Rate (CER) as a complementary metric, emphasizing the criticality of accuracy at each level of transcription.

Kafle and Huenerfauth [20] introduced a metric (modified ACE metric) that differs from WER by distinguishing between harmful and less harmful errors in captions. This approach recognizes the central role of spoken words in message comprehension and the semantic differences between erroneous words and their reference counterparts. By distinguishing between different types of errors and considering their impact on semantic coherence, this metric provides a nuanced framework for evaluating machine translation methods, recognition systems, and transcription correction techniques. As a result, it contributes significantly to assessing the effectiveness and accuracy of models developed for sign language translation and interpretation.

Table VI illustrates the key metrics for assessing the quality of automatic audio translation into sign language. Among these, the most frequently cited are BLEU and WER, each referenced six times. BLEU is employed to quantify the accuracy of translation in comparison to references, whereas WER assesses the word error rate in speech recognition. Notably, CER, which measures errors at the character level, was cited only once, indicating a relatively lower utilization compared to the other metrics.

TABLE VI
EVALUATIONS OF THE QUALITY OF AUDIO TRANSLATION INTO SIGN LANGUAGE USING NLP AND STT

Quality measurement assessments	Citations in articles
BLEU	6
WER	6
CER	1

D. SQ3 - What resources and dictionaries are available to assist in audio translation from Portuguese to Libras?

The Transformer model, introduced in the paper ”Attention Is All You Need”, revolutionized natural language processing by using attention mechanisms to handle complex token connections in sequences. This approach, combined with the use of ”masks” in the decoder, increases the efficiency and parallelizability of the model [22]. Another technique, LightConv, provides an alternative to Transformer by using depthwise convolutions to share output channels and normalize weights over time, effectively competing with self-attention models [23].

Tools such as VLibras and WikiLibras are essential for providing content in Brazilian Sign Language (Libras), and promoting digital inclusion for the deaf community [12], [24]. Recent studies show how these technologies improve communication and accessibility for deaf people, with an emphasis on automatic speech recognition and natural language processing [21].

In a study conducted by Veríssimo et al [25], the VLibras tool was used to generate glosses in Libras from Portuguese sentences, demonstrating its versatility and importance in digital accessibility and expanding the linguistic resources available to the deaf community. To obtain data for training NLP-based models, the study used Wikipedia articles to acquire approximately 5.8 million Portuguese sentences.

According to Bastas et al [21], automatic speech recognition and natural language processing technologies play a crucial role in sign language audio translation, especially in the context of the ”NLP-Theatre” system. This system incorporates the Google Speech-To-Text API and uses Kaldi, developed for streaming integration and implemented as a Docker container for image generation. The system, which is trained to detect errors in captions, instantly adjusts internal timing and adjusts content or playback speed as needed during playback.

The use of the Google Speech Recognition library enabled the transcription of Chinese and English into text in Kang study [17]. The CoreNLP tool was then used to segment and perform grammatical conversion of the resulting text. The authors use the ”reconversion” approach to reduce latency, which is essential for live captioning for deaf or hard-of-hearing people and can be corrected by human editing if the Automatic Speech Recognition (ASR) accuracy is acceptable [21].

Figure 5 provides a visual representation of the different tools and resources used for audio translation from Portuguese to Libras (Brazilian Sign Language) in the reviewed studies. Keywords such as ”GoogleAPI”, ”Hand Talk”, ”VLibras”, and ”Transformer” stand out in the word cloud, indicating their frequency in articles on the topic. In particular, ”GoogleAPI” suggests the availability of Google API or resources for facilitating audio translation between Portuguese and Libras.

Similarly, ”Hand Talk” probably represents a specific tool tailored for translation between the two languages. In addition, ”VLibras” is probably a dedicated resource or dictionary for Brazilian Sign Language. In essence, this word cloud highlights the availability of different tools and resources for audio translation between Portuguese and Libras, each with its unique features and potential contributions.

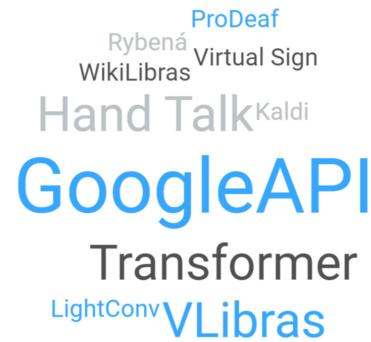

Fig. 5. Resources Available to Assist in Audio Translation

These studies underscore the application of automatic speech recognition and natural language processing technologies to improve communication and accessibility for deaf people and represent a significant step toward digital inclusion and the development of more comprehensive linguistic resources for the deaf community.

E. SQ4 - What is the comparative effectiveness of these tools in terms of accuracy, processing time, and accessibility for Libras users?

The comparative effectiveness of available tools for audio translation from Portuguese to Libras varies significantly in terms of accuracy, processing time, and accessibility for Libras users. OpenSigns has shown significant differences in Word Error Rate (WER) and BLEU scores, performing worse in understanding Brazilian Portuguese to Libras compared to VLibras, and similarly poor in translating English to Libras [12]. While Hand Talk provides users with autonomy through its illustrated dictionary and tutorial videos, it faces challenges such as translation errors when recorded by voice and difficulties with regional language variations. The Virtual Sign platform struggles with grammatical rules and syntax for each language, and its 3D avatar needs further improvement. Other tools, such as Signslator, SiMAX, Sign 4 Me, Hetah, ATLAS, and SASL-MT, aim to improve message comprehension for the deaf, but continue to face challenges in ensuring consistency and quality of content [12]. Overall, while these tools provide valuable support, there is still a need for improvements in accuracy, processing time, and accessibility to better serve Libras users.

IV. Challenges and Advances

In the study by Zhehan Kang [17], a system for translating spoken language into sign language was developed based on the HamNoSys system. The work addresses issues such as speech recognition and natural language processing, intending to create a practical sign language dictionary with animations for each sign, as well as establishing a speech-to-sign language translation system with high accuracy and practicality.

Ananthanarayana et al [19] evaluate the interpretation of signs into spoken language, highlighting the challenge of continuous sign language translation. The authors explore methods, including the use of Transformer models, to improve communication between deaf and hearing individuals, who are facing challenges with the American Sign Language (ASL) dataset due to its small size and the presence of noise.

Finally, the work of Brour and Benabbou [18] presents the ATLASLang NMT system for translating Arabic to Arabic Sign Language (ArSL) using a neural approach. This system shows significant improvements in the effectiveness of sentence translation, representing a major advance in the field of automatic translation.

The studies presented highlight significant advances and challenges in translation from spoken language to sign language. While advances in NLP show improvements in the effectiveness of automatic translation, it is still challenging to deal with large and noisy datasets, as well as to ensure the accuracy of translations, especially in sign languages with complex grammar. Studies on reinforcement learning techniques and model extensions such as Transformer may offer promising solutions to improve the quality and accuracy of translations.

Innovations in automatic translation from spoken language to sign language, such as those developed in the studies reviewed, have the potential to transform deaf education and assist teachers in the classroom. The development of highly accurate and practical translation systems, such as the one based on HamNoSys, can facilitate the rapid conversion of spoken educational content into comprehensible signs for deaf students. This can facilitate access to information in real-time, thereby reducing the communication barrier between teachers and deaf students and promoting more effective inclusion in the school environment.

Moreover, the deployment of models such as Transformer and ATLASLang NMT to enhance the translation of complex sentences can assist educators in the creation of pedagogical materials tailored to the requirements of deaf students. The potential for more accurate translation of academic content enables educators to ensure that students receive information that respects the grammatical structure of sign language, thereby facilitating more efficient and culturally relevant learning. Furthermore, these tools can be employed in interactive and multimedia activities, facilitating comprehension of complex concepts through the use of signs, thus contributing to a more inclusive and accessible education for all.

V. Conclusion

The systematic review of this research highlights the critical role of STT and NLP technologies in promoting accessibility and inclusion for the deaf community. While a variety of tools are available, each faces unique challenges such as limitations in accuracy and cultural adaptation. Metrics, such as BLEU score, WER, and CER, are essential for evaluating the quality of translations. Meanwhile, recent advancements, such as the Transformer and LightConv Machine Learning models, promise to improve the efficiency and accuracy of automated translation. However, there is still room for improvement, particularly in the areas of sign vocabulary expansion and cultural adaptation of translations. Future research could focus on developing more sophisticated models and working with the deaf community to ensure that the technologies developed meet their specific communication and accessibility needs.

References

[1] World Health Organization. (2024, January 25). Deafness and hearing loss. https://www.who.int/health-topics/hearing-loss

[2] de Souza, Q. R., da Silva Reis, E., da Costa Rocha, T. E., da Mota, O. M., de Souza Eler, R. R., & dos Santos França, S. (2020). INCLUSÃO NA UNIVERSIDADE FEDERAL DE RONDÔNIA/BRASIL: análise acerca da percepção de gestores x aluno/INCLUSION IN THE FEDERAL UNIVERSITY OF RONDÔNIA/BRAZIL: analysis of the perception of managers x student. Brazilian Journal of Development, 6(5), 25506-25520.

[3] Galasso, B. J. B., Lopez, M. R. D. S., Severino, R. D. M., Lima, R. G. D., & Teixeira, D. E. (2018). Processo de produção de materiais didáticos bilíngues do Instituto Nacional de Educação de Surdos. Revista brasileira de educação especial, 24, 59-72.

[4] Nogueira, C. M. I., Carneiro, M. I. N., & da Silva, T. D. S. A. (2018). O uso social das tecnologias de comunicação pelo surdo: limites e possibilidades para o desenvolvimento da linguagem. Revista Pesquisa Qualitativa, 6(12), 470-497.

[5] Lopes, D. D. Q., & Goettert, N. (2015). Tecnologias digitais e estratégias comunicacionais de surdos: a inclusão digital numa perspectiva bilíngue. Educação, 38(3), 358-368. doi: 10.15448/1981-2582.2015.3.21780

[6] Rodrigues, M., & Mill, D. (2019). A utilização do aplicativo hand talk para surdos, como ferramenta de melhora da acessibilidade na educação. Educação e Tecnologias: Experiências, Desafios e Perspectivas, 376-389.

[7] Shadiev, R., Hwang, W. Y., Chen, N. S., & Huang, Y. M. (2014). Review of speech-to-text recognition technology for enhancing learning. Journal of Educational Technology & Society, 17(4), 65-84.

[8] Tanberk, S., Dağlı, V., & Gürkan, M. K. (2021, September). Deep learning for videoconferencing: A brief examination of speech to text and speech synthesis. In 2021 6th International Conference on Computer Science and Engineering (UBMK) (pp. 506-511). IEEE. doi: 10.1109/UBMK52708.2021.9558954

[9] Indurkhya, N., & Damerau, F. J. (2010). Handbook of natural language processing. Chapman and Hall/CRC.

[10] Kitchenham, B. and Charters, S. (2007) Guidelines for Performing Systematic Literature Reviews in Software Engineering, Technical Report EBSE 2007-001, Keele University and Durham University Joint Report.

[11] Galvão, M. C. B., & Ricarte, I. L. M. (2019). Revisão sistemática da literatura: conceituação, produção e publicação. Logeion: Filosofia da informação, 6(1), 57-73.doi: 10.21728/logeion.2019v6n1.p57-73

[12] Costa, R. E., de Araújo, T. M., Lima, M. A., Veríssimo, V. M., de Andrade, R. S., Vieira, S. F., ... & Hanael, V. (2019). Towards an open platform for machine translation of spoken languages into sign languages. Machine translation, 33, 315-348.

[13] Andreis-Witkoski, S. (2020). Problematizando o uso do aplicativo de tradução Hand Talk no ensino da Libras no Ensino Superior. Educação, Ciência e Cultura, 25(3), 81-89.

[14] Bandeira, I. D. C., Camillo, J. C., da Costa Neto, L. P., Muniz, P. B. V., da Purificação Pinto, R., & Guimarães, R. P. B. (2018). O uso do hand talk como meio de inclusão para alunos com deficiência auditiva na educação profissional. Kiri-Kerê-Pesquisa em Ensino, (5).

[15] Oliveira, Tiago et al. The virtualsign channel for the communication between deaf and hearing users. IEEE Revista Iberoamericana de Tecnologias del Aprendizaje, v. 14, n. 4, p. 188-195, 2019.

[16] Veríssimo, V., Aschoff, M., Costa, R., Maritan, T., Vieira, S., & Santos, A. (2017, October). A Flexible Architecture for Building Ruled-Based Text-to-Gloss Machine Translators. In Proceedings of the 23rd Brazillian Symposium on Multimedia and the Web (pp. 473-480). doi: 10.1145/3126858.3126860.

[17] Kang, Z. (2019, September). Spoken language to sign language translation system based on HamNoSys. In Proceedings of the 2019 international symposium on signal processing systems (pp. 159-164).
[18] Brour, M., & Benabbou, A. (2021). ATLASLang NMT: Arabic text language into Arabic sign language neural machine translation. Journal of King Saud University-Computer and Information Sciences, 33(9), 1121-1131.
[19] Ananthanarayana, T., Srivastava, P., Chintha, A., Santha, A., Landy, B., Panaro, J., ... & Nwogu, I. (2021). Deep learning methods for sign language translation. ACM Transactions on Accessible Computing (TACCESS), 14(4), 1-30. doi: 10.1145/3477498
[20] Kafle, S., & Huenerfauth, M. (2017, October). Evaluating the usability of automatically generated captions for people who are deaf or hard of hearing. In Proceedings of the 19th International ACM SIGACCESS Conference on Computers and Accessibility (pp. 165-174).
[21] Bastas, G., Kaliakatsos-Papakostas, M., Paraskevopoulos, G., Kaplanoglou, P., Christantonis, K., Tsioustas, C., ... & Maragos, P. (2022, June). Towards a DHH Accessible Theater: Real-Time Synchronization of Subtitles and Sign Language Videos with ASR and NLP Solutions. In Proceedings of the 15th International Conference on PErvasive Technologies Related to Assistive Environments (pp. 653-661).
[22] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. Advances in neural information processing systems, 30.
[23] Wu, F., Fan, A., Baevski, A., Dauphin, Y. N., & Auli, M. (2019). Pay less attention with lightweight and dynamic convolutions. arXiv preprint arXiv:1901.10430. doi: 10.48550/arXiv.1901.10430
[24] De Oliveira, I. F., De Sousa, J. L. T., de Carvalho, L. C., Brito, M. D. O., de Aguiar Freire, K. M., & de Sousa Damasceno, A. C. (2020). A utilização do aplicativo vlibras como forma de ensino e aprendizagem para alunos surdos. Revista Psicologia & Saberes, 9(16), 22-30.
[25] Veríssimo, V., Silva, C., Hanael, V., Moraes, C., Costa, R., Maritan, T., ... & Gaudêncio, T. (2019, October). A study on the use of sequence-to-sequence neural networks for automatic translation of brazilian portuguese to libras. In Proceedings of the 25th Brazillian Symposium on Multimedia and the Web (pp. 101-108). doi: 10.1145/3323503.3360292