# Can Small VLMs Translate Sign Language to Spoken Language?

**Anonymous ACL submission**


## Abstract

Vision-Language Models (VLMs) have shown strong generalization across multimodal tasks, but their capacity to handle *sign language translation (SLT)*—which requires fine-grained spatiotemporal reasoning and linguistic understanding—remains unclear. In this study, we evaluate whether *small-scale VLMs* ($\leq$3B parameters) can perform SLT effectively. We conduct supervised fine-tuning using multilingual sign language datasets—DGS, ASL, and ISL—adopting parameter-efficient LoRA tuning applied to the language decoder, while keeping the vision encoder frozen and allowing the connector to be trainable. To evaluate translation quality, we propose entity- and semantics-aware metrics tailored for SLT. We highlight the data imbalance issues present in the above widely used SLT datasets. Our analysis highlights the limitations in applying general-purpose VLMs to SLT, unlike their applicability in other tasks, and provides insights to inform future development of VLMs for SLP, which is essential for building inclusive AI applications.


## 1 Introduction

Sign language serves as a vital mode of communication for the Deaf and Hard of Hearing (DHH) community, encompassing both manual components (e.g., hand gestures) and non-manual cues such as facial expressions, body posture, and eye gaze (Boyes Braem and Sutton-Spence, 2001). According to the World Health Organization[1], over 700 million people are expected to experience disabling hearing loss by 2050. To bridge the communication gap between DHH individuals and hearing populations, Sign Language Translation (SLT) aims to translate sign language videos into spoken or written text. However, the diversity of sign languages, each with unique grammar and regional variations, alongside their rich spatio-temporal structure, poses substantial challenges and is, therefore, attracting increasing attention from the deep learning community. Indeed, researchers have strongly advocated the development of NLP tools for sign language understanding (Yin et al., 2021).

Unlike Sign Language Recognition (SLR), which predicts glosses or isolated labels, SLT requires models to capture the semantic, temporal, and syntactic intricacies of continuous signing. SLT methods typically fall into two categories: gloss-based and gloss-free. The former follows a two-step pipeline that first predicts glosses and then translates them into natural language (Camgoz et al., 2018, 2020; Zhou et al., 2021; Chen et al., 2022a; Zhou et al., 2022; Chen et al., 2022b), whereas the latter directly generates the translation bypassing the direct involvement of gloss annotation (Lin et al., 2023; Gong et al., 2024; Wong et al., 2024). Recent progress has been driven by transformer-based architectures (Vaswani et al., 2017) that take a visual sequence as input into a spatio-temporal encoder and generate a context-aware translation with a decoder which is essentially a large language model (LLM) (Gong et al., 2024; Jang et al., 2025; Wong et al., 2024).

Recent advancements in LLMs such as GPT-3 (Brown et al., 2020) and LLaMA (Touvron et al., 2023) demonstrated strong language understanding, reasoning, and multilingual translation by leveraging large-scale web corpora. Building on these capabilities, vision-language models (VLMs) like CLIP (Radford et al., 2021), BLIP (Li et al., 2022), LLaVA (Liu et al., 2023), and Qwen2.5-VL (Bai et al., 2025) aligned visual content with textual semantics and achieved state-of-the-art results across several multimodal tasks, demonstrating strong temporal and visual reasoning – skills also essential for SLT. Although scaling model size has led to performance gains across many domains (Chowd-

[1] https://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss

hery et al., 2023; Alayrac et al., 2022; Liu et al., 2023), these large models often require considerable computational resources and are difficult to deploy in real-world or low-resource settings. This led the research interest in more efficient and scalable architectures.

Motivated by the advancement in both fields, we aim to investigate whether the multimodal or visual language models (Yin et al., 2024; Caffagni et al., 2024) can perform SLT effectively. In particular, we conduct supervised fine-tuning of off-the-shelf small-scale VLMs with a frozen visual model, trainable connector (modality aligner), and a LoRA tunable language model. Note that this fine-tuning methodology has shown a promising performance in several challenging tasks like radiology report generation (Chen et al., 2025; Kapadnis et al., 2024; He et al., 2025) and science question-answering (Kim et al., 2023). We also note that full fine-tuning of the VLM is computationally very expensive and infeasible with our infrastructure. Thus, our central research question is, *Can small-scale vision-language models, originally trained for generic video-language tasks, be effectively adapted for the specialized task of sign language translation?* This question is particularly challenging because SLT is significantly different from usual video understanding tasks like captioning and question-answering.

In this work, we present the first systematic evaluation of general-purpose small VLMs for SLT, revealing that these models fall severely short of specialized SLT systems. Our key contributions are: (i) We conducted comprehensive experiments with four sign language datasets and two small VLMs across model sizes and fine-tuning types under resource-constrained settings where the vision encoder is frozen; (ii) Our experiments demonstrate consistent underperformance of VLMs in SLT; (iii) We uncover vocabulary biases in benchmark datasets that influence model outputs; and (iv) We introduce two targeted evaluation metrics, *translation soft-recall* and *psuedo-gloss entity-recall*, to better capture the semantic fidelity in SLT outputs. We will publicly release our code (upon acceptance of our manuscript).

## 2 Related Work

### 2.1 Sign Language Translation

Recent advances in SLT have transitioned from early RNN-based architectures to Transformer-based models (Vaswani et al., 2017), to better capture long-range dependencies in video sequences (Camgoz et al., 2018, 2020). Early approaches typically followed a gloss-based pipeline, first translating videos into intermediate glosses and then generating natural language text. These methods were enhanced through spatial-temporal modeling (Zhou et al., 2022), hierarchical representations (LI et al., 2020), two-stream architectures (Chen et al., 2022b), and hand-aware representation learning (Hu et al., 2021, 2023). However, the reliance on annotated glosses limited scalability, prompting a shift toward gloss-free approaches that directly map videos to text. These include attention-based encoders (Lin et al., 2023; Yin et al., 2023), contrastive learning (Gan et al., 2023), dense representation modeling (Ye et al., 2024), and keypoint-driven models (Chen et al., 2022a). Recent works have developed customized VLMs for direct gloss-free translation by aligning visual features with frozen language models (Gong et al., 2024; Wong et al., 2024; Hwang et al., 2025), supported by factorized adaptation (Chen et al., 2024), contextual reasoning (Jang et al., 2025), and video-language alignment pretraining (Jiao et al., 2025). Several studies also explored multilingual and continual learning settings (Yazdani et al., 2025; Zhang et al., 2024). Common datasets include PHOENIX-2014T (German) (Camgoz et al., 2018), How2Sign (American Sign Language) (Duarte et al., 2021), and OpenASL (ASL) (Shi et al., 2022).

### 2.2 Vision-Language Models

Following the success of LLMs like GPT-3 and LLaMA, researchers have attempted to incorporate multiple modalities beyond text into the foundation models. Multimodal large language models (MLLMs) and VLMs have emerged as their natural successor (Caffagni et al., 2024), and they support downstream tasks such as video captioning (Nadeem et al., 2024), video question answering (Zou et al., 2024; Xiao et al., 2024; Wang et al., 2025), and long video understanding (Ranasinghe et al., 2025), where cross-modal and temporal alignment is essential. These tasks can be achieved by zero or few-shot prompting. Fine-tuning, if necessary, is generally done on the LLM and the connector between the visual encoder and text decoder (Li et al., 2023; Yin et al., 2024). Recent research has also focused on developing smaller VLMs like SmolVLM2 (Marafioti et al., 2025), BLIP-2 (Li et al., 2023), TinyLLaVA (Zhou et al., 2024), and

Qwen-2.5B-VL (Bai et al., 2025), which contain fewer than 3B parameters, which are attractive for resource-constrained and real-time deployments. However, it is unclear whether these models are suitable for SLT, and the papers that introduce these models do not mention if they have been trained or evaluated for sign language processing tasks despite their importance in creating inclusive AI systems. This paper aims to address that gap.

# 3 Method

## 3.1 Overview

Given a sign language video $V = [f_1, f_2, \cdots, f_T]$ with a sequence of $T$ frames, the goal of SLT is to generate a spoken language sentence $Y = [w_1, w_2, \cdots, w_S]$, where $S \ll T$. Unlike recent works that design specialized transformer-based models to convert $V$ to $Y$, we explore whether off-the-shelf VLMs, supporting video inputs, are suitable for this purpose since they are already pre-trained on large visual-text corpora. We choose small VLMs as they are more resource-friendly. Our model, shown in Figure 1, consists of a frozen vision encoder, a trainable connector which is a multi-layered perceptron, and a language model (LM). While the vision model extracts frame-level features from $V$, the connector projects them into the language embedding space, and the LM generates the final spoken language text. The connector is trained and the LM is fine-tuned.

## 3.2 VLM Selection.

We have selected two recent VLMs that strike a balance between efficiency and performance. The first is **SmolVLM2** (Marafioti et al., 2025), a 2.2B parameter model designed for edge deployment, known for its lightweight architecture and strong multimodal capabilities. SmolVLM2 is built on Idefics3 (Laurençon et al., 2024), comprising a 27-layer SigLIP-SO400M (Zhai et al., 2023) vision encoder and a 24-layer LLaMA 3.1 (Grattafiori et al., 2024) language model, connected via an MLP-based modality bridge. SmolVLM2 2.2B model achieves state-of-the-art performance on many image and video understanding tasks among open-weights models of similar scale, while being more resource-efficient (Marafioti et al., 2025). The second model we choose is **Qwen2.5-VL** (Bai et al., 2025), a 3B parameter architecture that integrates a 32-layer Vision Transformer (ViT) with efficient windowed attention and a 36-layer Qwen2.5 language model. Like SmolVLM2, it employs an MLP-based connector to merge visual and linguistic representations effectively.

## 3.3 Frame Sampling Strategy

Sign language videos vary widely in duration, with sequences ranging from a few frames to several hundred. However, the VLMs used in this study, namely, SmolVLM2 and Qwen2.5-VL, have a short context size (e.g., 8K tokens for SmolVLM2) which constrains the number of video frames to, say, $T_{max}$, depending on the size of the input image patches and the model's internal architecture (e.g., 64 for SmolVLM2 with default settings). The model features are shown in Table 1.

To ensure that each video is processed efficiently within this limit, we judiciously select a frame count $T_{\max}$ based on the model's capacity and the video length distribution. In particular, given a video with $T$ total frames, where $T > T_{\max}$, we divide the sequence into $T_{\max}$ equal-length intervals and select one representative frame per interval. The representative frame $f_i$ in each interval is selected deterministically using:

$$f_i = \textbf{frames}\left[\left\lfloor \frac{(i+1)\cdot T}{T_{\max}} \right\rfloor - 1\right],$$
$$i = 0, 1, \ldots, T_{\max} - 1.$$

where **frames**$[\cdot]$ denotes frames whose indices appear in $[\cdot]$. This ensures a uniform spread of selected frames across the entire video duration. If $T \leq T_{\max}$, we retain all frames without modification.

Note that we do not use random skipping as it may drop critical frames, disrupting semantic continuity. The final output is a list of $T_{\max}$ or fewer frames, sampled in a way that balances global coverage and local coherence. Our design choice ensures fair and consistent evaluation across variable-length sign language videos while adhering to the strict frame limits imposed by our chosen VLMs.

## 3.4 Finetuning VLMs

The language models were tuned using the parameter-efficient Low-Rank Adaptation (LoRA) method (Hu et al., 2022), which allowed us to update only a small subset of parameters while maintaining the general linguistic capabilities of the models. We observed consistent performance improvements with the use of LoRA over full

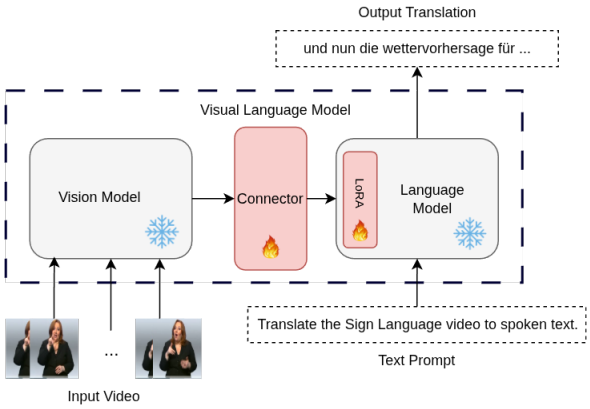


Figure 1: Overview of our vision-language model architecture for sign language translation.

fine-tuning (see Table 8), particularly in resource-constrained settings. Note that the encoder was kept frozen while the connector was trained along with the LM.

| Model | No. of Parameters | Vision Model (No. of layers) | Language Model (No. of layers) | Input Context Length |
|---|---|---|---|---|
| SmolVLM2 | 2.2B | SigLIP (27) | LLaMA-3.1 (3.1) | 8K |
| Qwen2.5-VL | 3B | ViT (32) | Qwen2.5LM (36) | 32K |

Table 1: Overview of Selected VLM Architectures

# 4 Experiments

## 4.1 Datasets

We evaluated our approach on four publicly available sign language translation datasets spanning German, American, and Indian sign languages. While some of these datasets included intermediate gloss annotations (e.g., PHOENIX-2014T), our training does not rely on gloss supervision. Instead, we focus on learning a direct mapping from sign language videos to natural language text.

**German Sign Language (DGS)**: The RWTH-PHOENIX-Weather 2014T dataset (Camgoz et al., 2018) serves as a standard benchmark for DGS translation. It consists of 7,096 training, 519 validation, and 642 test samples aligned with German sentences. With a vocabulary of 2,887 words, it captures weather forecast scenarios performed by professional interpreters on television.

**American Sign Language (ASL)**: OpenASL (Shi et al., 2022) is a large-scale ASL dataset collected from online videos across a wide range of topics. It includes 98,417 video-sentence pairs, featuring over 200 signers, of which 966 samples are reserved for validation and 975 for testing. We also use the How2Sign (Duarte et al., 2021) dataset, which provides around 120 hours of ASL content derived from instructional videos, with 31,128 training, 1,741 validation, and 2,322 test samples. It includes multi-view videos and additional modalities such as speech, keypoints, and depth maps.

**Indian Sign Language (ISL)**: iSign (Joshi et al., 2024) is a recently introduced large-scale dataset for Indian Sign Language, offering over 127K sentence-aligned signing videos from diverse, real-world contexts. Due to its scale, we carefully select a subset of 50K examples: 43K for training and 3.5K each for validation and test, preserving linguistic diversity while ensuring that the sample size is not too large to train our models. More details of the selection process are provided in Appendix A.

## 4.2 Evaluation Metrics

**Standard Metrics.** To evaluate the translation quality of sign language outputs, we have used standard metrics widely adopted in the machine translation literature: BLEU (Papineni et al., 2002) and ROUGE-L (Lin and Och, 2004). BLEU captures $n$-gram precision by comparing predicted translations to ground-truth references, and we reported scores from BLEU-1 through BLEU-4 using the SacreBLEU[2] implementation. ROUGE-L measures the longest common subsequence between the prediction and reference; it captures how well the predicted sentence preserves the sequence of the target, without requiring a predefined $n$-gram length.

**Semantic Fidelity in SLT.** Given the generative properties of LMs, it is possible that the LM's output does not match the ground-truth translation but is still semantically correct. To capture this aspect, we introduce two metrics: *Translation Soft Recall* (TSR) and *Pseudo-Gloss Entity Recall* (PGER), which are adaptations of Heading Soft Recall (Fränti and Mariescu-Istodor, 2023) and Heading Entity Recall (Shao et al., 2024), respectively. The former computes semantic similarity between predicted and reference sentences using cosine similarity of embeddings from the multilingual Sentence Transformer model `paraphrase-multilingual-MiniLM-L12-v2`[3].

[2] https://github.com/mjpost/sacrebleu

[3] https://huggingface.co/sentence-transformers/paraphrase-multilingual-MiniLM-L12-v2

This captures meaning beyond exact wording and can better handle paraphrase variations. The PGER metric is motivated by the observation that signers often emphasize key content words such as nouns, verbs, and adjectives. We extract these entities using FLAIR (Akbik et al., 2019) part-of-speech tagging and compute their overlap between prediction and reference, treating them as proxies for underlying glosses.

$$\mathcal{C}(Z) = \sum_{i=1}^{|Z|} \frac{1}{\sum_{j=1}^{|Z|} \mathit{Sim}(Z_i, Z_j)} \quad (1)$$

$$\text{TSR}(Y, \hat{Y}) = \frac{\mathcal{C}(Y) + \mathcal{C}(\hat{Y}) - \mathcal{C}(Y \cup \hat{Y})}{\mathcal{C}(\hat{Y})} \quad (2)$$

$$\text{PGER}(Y, \hat{Y}) = \frac{|\mathit{Ent}(Y) \cap \mathit{Ent}(\hat{Y})|}{|\mathit{Ent}(Y)|} \quad (3)$$

Here, $Y$ and $\hat{Y}$ represent the ground truth and predicted translations, respectively. $\mathit{Ent}(\cdot)$ denotes the set of entities extracted from a translation. $\mathcal{C}(Z)$ refers to the soft cardinality of the set $Z$ (Fränti and Mariescu-Istodor, 2023). The function $\mathit{Sim}(\cdot, \cdot)$ computes the cosine similarity between the embeddings of word $Z_i$ and $Z_j$ within the same translation. These metrics quantify how well a model preserves meaning while using words different from those in the golden output. To our knowledge, this is the first application of such entity- and semantics-aware metrics in SLT, providing deeper insights into translation faithfulness.

### 4.3 Implementation Details

Our implementation has been done on the PyTorch framework, and experiments were conducted using a single NVIDIA A100 GPU. A more detailed system specification is provided in the Appendix F.

**Network Details.** We fine-tuned two open-source VLMS from Hugging Face repository: **SmolVLM2-2.2B-Instruct**[4] and **Qwen2.5-VL-3B-Instruct**[5]. Both models were trained for **10 epochs**, using sampled video inputs of length $T_{\max} = 64$ frames. Frame statistics for all datasets are detailed in Table 2. We froze the vision encoder in both cases and kept a lightweight connector module fully trainable. We applied LoRA-based parameter-efficient fine-tuning to the language model, specifically targeting the attention and MLP projection layers. Following the default settings in each case, (1) for **SmolVLM2**, we used a LoRA rank of $r = 64$, scaling factor $\alpha = 64$, and a dropout of 0.1; (2) For **Qwen2.5-VL-3B**, we used the same LoRA rank and scaling factor but a dropout of 0.05.

| Dataset | Total videos | Avg. frame count | Frame count $> 300$ |
|---|---|---|---|
| PHOENIX-2014T | 7,096 | 116.59 | 23 |
| How2Sign | 31,047 | 162.76 | 3,772 |
| OpenASL | 97,233 | 205.25 | 24,752 |
| iSign | 127,237 | 209.08 | 23,767 |

Table 2: Video-level statistics across different datasets used in our experiments. We report the total number of videos, the average number of frames per video, and the number of videos with more than 300 frames.

**Training and Inference Details.** We trained the models using the Hugging Face `Trainer`, with FlashAttention-2 enabled and all computations performed in `bfloat16` precision. For **SmolVLM2**, we used the AdamW optimizer with a learning rate of $1 \times 10^{-4}$, a per-device batch size of 1, and gradient accumulation steps of 4. For **Qwen2.5-VL-3B**, we adopted a cosine learning rate schedule with a base learning rate of $1 \times 10^{-5}$, also applied to the connector; the batch size and gradient accumulation settings remained unchanged. For both models, during inference, we set the maximum generation length to 128 tokens and applied greedy decoding to preserve alignment between video semantics and textual output. The prompt used for fine-tuning and inference is presented in Appendix E.

### 4.4 Results

Table 3 reports the evaluation results using BLEU (1–4) and ROUGE-L scores on the validation (val or dev) and test sets for the four selected datasets and the two selected models. SmolVLM2 consistently outperformed Qwen2.5-VL across all datasets. On PHOENIX-2014T, SmolVLM2 achieved a BLEU-4 score of 8.43 on the test set, significantly higher than Qwen2.5-VL's 2.78. Similar improvements were observed on How2Sign, OpenASL, and iSign, with SmolVLM2 producing consistently higher BLEU and ROUGE scores.

To assess translation quality at a deeper semantic level, we adopted *Pseudo-Gloss Entity Recall* and *Translation Soft Recall*. Results in Table 4 and Ta-

[4] https://huggingface.co/HuggingFaceTB/SmolVLM2-2.2B-Instruct

[5] https://huggingface.co/Qwen/Qwen2.5-VL-3B-Instruct

| Model | Dev Set | | | | | Test Set | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BLEU-1 | BLEU-2 | BLEU-3 | BLEU-4 | ROUGE-L | BLEU-1 | BLEU-2 | BLEU-3 | BLEU-4 | ROUGE-L |
| RWTH-PHOENIX-Weather 2014T (German Sign Language) | | | | | | | | | | |
| SmolVLM2 | **25.53** | **15.51** | **10.11** | **7.80** | **25.91** | **24.15** | **14.89** | **10.16** | **8.44** | **24.51** |
| Qwen2.5-VL | 7.62 | 3.25 | 2.98 | 2.56 | 9.98 | 7.87 | 3.43 | 3.09 | 2.78 | 9.79 |
| How2Sign (American Sign Language) | | | | | | | | | | |
| SmolVLM2 | **6.83** | **1.46** | **0.23** | **0.04** | **8.38** | **6.84** | **1.56** | **0.28** | **0.06** | **8.38** |
| Qwen2.5-VL | 2.45 | 0.74 | 0.21 | 0.01 | 4.83 | 2.80 | 0.75 | 0.18 | 0.02 | 5.05 |
| OpenASL (American Sign Language) | | | | | | | | | | |
| SmolVLM2 | **7.64** | **1.91** | **1.05** | **0.79** | **8.47** | **7.06** | **1.20** | **0.60** | **0.41** | **7.78** |
| Qwen2.5-VL | 3.24 | 0.30 | 0.11 | 0.01 | 4.31 | 3.52 | 0.29 | 0.08 | 0.07 | 4.46 |
| iSign (Indian Sign Language) | | | | | | | | | | |
| SmolVLM2 | **7.47** | **1.27** | **0.60** | **0.39** | **8.09** | **7.59** | **1.37** | **0.65** | **0.44** | **8.21** |
| Qwen2.5-VL | 2.48 | 0.27 | 0.15 | 0.13 | 3.85 | 2.51 | 0.33 | 0.22 | 0.18 | 3.87 |

Table 3: **Sign language translation results** across four datasets in German (RWTH-PHOENIX-Weather 2014T), American (How2Sign, OpenASL), and Indian (iSign) sign languages. We report BLEU (1–4) and ROUGE-L scores for both validation (Dev) and test sets using SmolVLM2 and Qwen2.5-VL.

ble 5 show that SmolVLM2 produces higher scores in all cases.

Thus, **SmolVLM2** consistently outperformed **Qwen2.5-VL** across all datasets on both lexical and semantic-level metrics. It can be observed the BLEU and ROUGE-L scores for all datasets, except PHOENIX-14T, are very low. Therefore, for ASL and ISL datasets, the generated translations are of extremely poor quality. Hence, we peform further analysis only on PHOENIX-14T.

| Model | PHOENIX -2014T | How2Sign | OpenASL | iSign |
|---|---|---|---|---|
| SmolVLM2 | **0.1372** | **0.0678** | **0.0318** | **0.0190** |
| Qwen2.5-VL | 0.0221 | 0.0428 | 0.0128 | 0.0143 |

Table 4: Pseudo-Gloss Entity Recall (PGER) based on key content words (noun, verb, adjective) on test sets. Higher is better.

| Model | PHOENIX -2014T | How2Sign | OpenASL | iSign |
|---|---|---|---|---|
| SmolVLM2 | **0.7422** | **0.3102** | **0.2538** | **0.2611** |
| Qwen2.5-VL | 0.4857 | 0.3091 | 0.179 | 0.1195 |

Table 5: Translation Soft Recall (TSR) scores on test sets across datasets. Higher is better.

#### 4.4.1 Qualitative Analysis of Translation Results

We examine a few cases from PHOENIX-2014T test set to understand the types of errors committed by SmolVLM2. The cases displayed in Table 7 reveals two recurring types of translation errors. First, the model frequently failed at entity grounding, for example, misidentifying specific dates or days (e.g., predicting *May 30th* instead of the correct *October 15th*). Second, it often hallucinated semantically plausible but incorrect content—such as adding weather details like "rain in the north," that were absent in the reference. These patterns indicate that translation of the SmolVLM2 frequently lacked precise alignment between the visual input and the target linguistic output. Additional results on various datasets are provided in Appendix B while a more detailed breakdown focused on noun-phrase-level performance and qualitative examples appear in Appendix C.

#### 4.4.2 Vocabulary Bias and Overfitting Tendencies

We have observed that some words are very frequently present in the generated translation, and they often appear in place of the right word in the output. So we ask: Does the training set have a specific bias towards some set of words? To investigate it, we select the PHOENIX-2014T dataset and pick the top ten most frequent words and noun phrases in the predicted translations from the SmolVLM2 model. While we notice several high-frequency tokens (e.g., `und`, `es`, `im`) appeared consistently across all sets, words such as `süden` and `norden` were notably overrepresented in predictions despite being much less frequent in the test set, and they were also high frequency words in the training set. This reflects a tendency of the model to overgener-

ate words that were more prominent in the training distribution. Similar trends were also observed in the noun phrase results. A more detailed comparison of vocabulary distributions across the predicted, test, and training sets is provided in Appendix D.

These tendencies of biasness motivated us to carry out a vocabulary analysis across the training set of all four datasets and the frequency of each unique word; details of the analysis are presented in Table 2. All datasets demonstrated a highly skewed distribution, with the majority of tokens occurring fewer than ten times. In particular, over 70% of the vocabulary in OpenASL and iSign fell into this low-frequency range. This long-tailed nature of the data likely contributed to the model's generation of high-frequency terms, impacting its ability to produce rare or diverse words during inference.

| Dataset | No. of Tokens | No. of Unique Token | Token Freq.<10 | Token Freq >100 |
|---|---|---|---|---|
| PHOENIX-2014T | 99,081 | 2,887 | 2,083 | 182 |
| How2Sign | 41,421 | 3,577 | 3,105 | 65 |
| OpenASL | 13,71,021 | 29,197 | 21,335 | 1,561 |
| iSign | 13,20,855 | 33,498 | 25,304 | 1,517 |

Table 6: Vocabulary statistics of different sign language datasets, including total token counts, number of unique tokens, and the distribution of rare (frequency < 10) and frequent (frequency > 100) tokens.

## 5 How do these results compare to SOTA?

Our findings show that small-scale VLMs, even with their LMs fine-tuned on sign language data, fail to achieve competitive performance on standard sign language translation benchmarks. The SOTA methods show a BLEU-4 score of 24.32 in the test set of the PHOENIX-2014T dataset, and 10.11 BLEU-4 on the test set of the How2Sign dataset (Hwang et al., 2025). While OpenASL is less explored due to its scale, the BLEU-4 score on its test set is 7.06 (Lin et al., 2023). iSign is a more recent dataset that has a SOTA BLEU-4 of 1.47 (Joshi et al., 2024). These numbers are *substantially higher* than the scores we obtained. We observe that the SOTA models employ very specialized architectures, though mostly based on transformers, that usually rely on training the vision encoder using pseudo-gloss (Lin et al., 2023; Gong et al., 2024) or visual-language pretraining to adapt the visual encoder to the complexities of sign language (Zhou et al., 2023) or designing modules to precisely capture spatial configurations and motion dynamics present in sign language (Hwang et al., 2025). Clearly, general-purpose vision-language foundation models lack the inductive biases and task-specific training necessary to capture the spatiotemporal complexities of sign language, and this cannot be addressed simply by training the LM. This is likely because the models are exposed to little or no sign language data during pretraining, and is also not instruction-tuned on sign language processing tasks.

## 6 Ablation Study

**Model Parameter Selection and Fine-tuning Strategy:** We investigated three scales of the SmolVLM2 model (Marafioti et al., 2025)—256M, 500M, and 2.2B parameters—across various fine-tuning strategies. Full fine-tuning of the 256M model yielded poor performance and was therefore not pursued further. Due to resource constraints, full fine-tuning of the 500M model was impractical, so we explored partial strategies: i) tuning only the vision or language models, ii) sequentially tuning both, with the connector being trained with the language model (LM) and iii) applying LoRA to only LM while keeping the vision encoder frozen and fully training the connector.

| Model Size | Fine-tuning Strategy | BLEU1 | BLEU2 | BLEU3 | BLEU4 | ROUGE-L |
|---|---|---|---|---|---|---|
| 256M | Full | 11.2801 | 3.1971 | 1.3475 | 0.9809 | 11.5488 |
| 500M | LM only | 21.1849 | 11.3004 | 7.0104 | 5.7513 | 20.8966 |
| 500M | Vision model only | 20.0229 | 9.8091 | 6.1418 | 4.9888 | 20.6542 |
| 500M | Vision then LM | 22.3609 | 12.0529 | 7.8071 | 6.0799 | 21.9553 |
| 500M | LoRA for LM | **23.1022** | 12.7053 | 7.8365 | 6.1264 | **23.4076** |
| 2.2 B | LoRA for LM | 22.2051 | **12.7622** | **8.2799** | **6.5134** | 22.5206 |

Table 8: Ablation study comparing different SmolVLM2 model sizes and fine-tuning strategies on the PHOENIX-2014T test set (after 5 epochs). We report BLEU-1 to BLEU-4 and ROUGE-L scores.

The nature of the experimental results in the third category of experiments of 500M, we also scaled up to a 2.2B model with a similar strategy. This setup yielded the best overall results (Table 8), demonstrating that targeted fine-tuning of larger models led to significant performance gains without incurring the cost of full training.

**Effect of Frame Length on Translation Quality:** To maintain compatibility with SmolVLM2's architectural constraints—specifically, a maximum

| | |
|---|---|
| Ground Truth: | und nun die wettervorhersage für morgen freitag den fünfzehnten oktober |
| Englih Translation | And now the weather forecast for tomorrow, Friday, October 15th. |
| SmolVLM2: | und nun die wettervorhersage für morgen freitag den dreißigsten mai |
| English Translation | And now the weather forecast for tomorrow, Friday, May 30th. |
| Qwen2.5-VL: | und nun die neue richtung |
| English Translation | And now the new direction. |
| Ground Truth: | und nun die wettervorhersage für morgen donnerstag den fünfzehnten oktober |
| Englih Translation | And now the weather forecast for tomorrow, Thursday, October 15th. |
| SmolVLM2: | und nun die wettervorhersage für morgen montag den achtundzwanzigsten oktober |
| English Translation | And now the weather forecast for tomorrow, Monday, October 28th. |
| Qwen2.5-VL: | und nun die wettervorhersage für morgen montag den neunzehnten oktober |
| English Translation | and now the weather forecast for tomorrow, Monday, October 19th. |
| Ground Truth: | am freitag ist es in der nähe der küsten und ganz im süden teilweise stark bewölkt |
| Englih Translation | On Friday, it will be partly cloudy near the coast and in the far south. |
| SmolVLM2: | am freitag ist es im süden und osten weiter freundlich im norden regnet es gebietsweise |
| English Translation | On Friday, it will remain pleasant in the south and east, with rain in some areas in the north. |
| Qwen2.5-VL: | und jetzt wünsche ich ihnen noch einen schönen abend |
| English Translation | and now I wish you a nice evening. |

Table 7: Translation examples from test set of PHOENIX-2014T dataset for the two models. We highlight the errors in translation in red and the corresponding ground-truth in blue.

of 64 frames at 384p resolution[6]—we standardized all experiments to 64-frame video inputs. To assess whether longer sequences improved translation quality, we fine-tuned Qwen2.5-VL (Bai et al., 2025) with a context length of 256 frames on the Phoenix-2014T dataset.

| Max Frames | BLEU1 | BLEU2 | BLEU3 | BLEU4 | ROUGE-L |
|---|---|---|---|---|---|
| 64 | **7.8711** | **3.4272** | **3.0888** | **2.784** | **9.7947** |
| 256 | 6.4473 | 2.2679 | 2.0075 | 1.7449 | 7.4508 |

Table 9: Impact of Input Frame Length on Translation Performance for Qwen2.5-VL Fine-Tuned on PHOENIX-2014T

Results in Table 9 show that increasing the frame count from 64 to 256 consistently reduced performance, suggesting that the model is not capable of accurately processing longer videos. Based on these findings, we adopted 64-frame inputs for all models to balance translation quality with computational efficiency.

## 7 Conclusion

In this work, we analyse the relevance of off-the-shelf VLMs in SLT task. Our findings show that the direct integration of VLM with fine-tuning only the language model (and not the vision encoder), which shows promising results in other domains, fails to produce satisfactory performance in the SLT task. This highlights a significant limitation of foundation models when it comes to the development of inclusive AI tools and frameworks. In particular, it is necessary to incorporate sign language understanding objectives in the pretraining and instruction-tuning phases of these models so that they can be used with zero or few-shot prompting for sign language translation and other related tasks for the more common sign languages, and can be easily adapted to various other sign languages with limited fine-tuning.


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## Limitations

In this work, we made our architectural choices and set the video context length based on the resource constraints of our computational facility. To reduce the high computational demand, we kept the vision model frozen. Although end-to-end training was not feasible under our current constraints, we plan to train the vision model separately in future work and examine whether this leads to improved

[6] https://huggingface.co/HuggingFaceTB/SmolVLM2-2.2B-Instruct/blob/main/preprocessor_config.json

performance. Additionally, we studied the severe data imbalance present in popular sign language datasets but did not provide a solution for this issue in the current work. Our experiments were limited to two small VLMs and four sign language translation datasets, which could be expanded in future work.

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## Appendix

This appendix provides additional details and analyses that support our main findings. It includes insights into dataset preparation, translation behavior, grounding errors, vocabulary analysis, and resource usage.

### Appendix Table of Contents


- A Dataset Selection and Splitting Strategy
- B Qualitative Analysis of Translation Results
- C Error Patterns in Noun Phrase Grounding
- D Vocabulary Bias and Distributional Influence
- E Prompt Used during Training and Testing
- F Computational Resources


## A Dataset Selection and Splitting Strategy for iSign

The iSign dataset contains noise at various places. For example, some videos do not have any human presence as illustrated in Figure 2, while some have no valid translation texts. To improve the dataset quality, we first applied two basic cleanup steps: removing samples without valid textual translations and filtering out videos with no visually detectable human presence using pose estimation.

Figure 2: Frames sampled from a video with id *aTB_lu2Im8Y–129* showing no human presence from iSign dataset.

To efficiently fine-tune a small VLM, we reduced our dataset from 126,000 to 50,000 video-text pairs. Rather than applying random sampling, we followed a vocabulary-aware strategy as follows. A vocabulary frequency analysis revealed that over 75% of the words in the dataset occurred fewer than 10 times. These *rare words* are essential for balancing the overall vocabulary spectrum, yet they also pose a challenge for model generalization. To strike a balance, we first selected up to 30,000 samples that contained at least one rare word. We then sampled an additional 20,000 examples from the rest of the dataset, which ensures both rare and frequent expressions are present in the data subset we used.

This method ensures that the model is trained on a wide vocabulary, especially low-frequency tokens, while the validation and test sets remain challenging but not overly skewed toward rare or unseen words. The result is a dataset that better supports robust and generalizable model training.

## B Qualitative Analysis of Translation Results.

As shown in Tables 10 and 11, we provide a few representative translation outputs from the OpenASL and iSign datasets. While the overall translation quality across both models is poor, we include a mix of relatively better and worse examples to highlight common trends. In many cases, outputs fail to preserve critical entities or semantic meaning, underscoring the challenges of sign language translation in current settings. Although SmolVLM2 tends to generate slightly better translation in some cases, the overall performance of both models shows poor quality translation.

| | |
|---|---|
| Ground Truth: | I am Ed Bosson, and I am 67 years old and now retired. |
| SmolVLM2: | Hello, my name is E. Simmons and I am a retired school administrator. |
| Qwen2.5-VL: | I'm Ez Sussy. |
| Ground Truth: | We are also supporting efforts of DeafBlind people to develop hospital access because their needs are different from other deaf and hard of hearing people. |
| SmolVLM2: | The IDEA has been in place since 1975, and with the passing of the EHDI Act in 2007, all deaf and hard of hearing children have a birth stage in education. |
| Qwen2.5-VL: | I will show you how to do it. |
| Ground Truth: | Thank you! |
| SmolVLM2: | Congratulations! |
| Qwen2.5-VL: | Congrats and Congratulations! |
| Ground Truth: | I'm Crystal Cousineau |
| SmolVLM2: | I'm Crystal Cousineau |
| Qwen2.5-VL: | CRY. |
| Ground Truth: | The gunman is behind bars being held without bail |
| SmolVLM2: | It took about that same time for his owner to get down on one knee and say \"I love you\" in Spanish. |
| Qwen2.5-VL: | The suspect was arrested and is 17 years old |
| Ground Truth: | I'm Candace Jones. |
| SmolVLM2: | Thank you for watching Sign1News. |
| Qwen2.5-VL: | I'm Crystal Cousineau. |

Table 10: Translation examples from test set of **OpenASL** dataset, where we highlight the partial matches in blue.

| | |
|---|---|
| Ground Truth: | What is the RAT test? |
| SmolVLM2: | The cost of the surgery is around Rs 2 lakhs. |
| Qwen2.5-VL: | and now there is an update |
| Ground Truth: | Have a look at images. |
| SmolVLM2: | Have a look at images. |
| Qwen2.5-VL: | She is a 30 year old woman |
| Ground Truth: | The priest sanctified the church with a special ceremony. |
| SmolVLM2: | The priest sanctified the church with a special ceremony. |
| Qwen2.5-VL: | The priest sanctified the church with a |
| Ground Truth: | and the ingredients should only be added when the fire is burning properly |
| SmolVLM2: | so that you can get all your essential nutrients |
| Qwen2.5-VL: | ISH NEWS has already made a video on this, you can watch it on our YouTube channel. |
| Ground Truth: | People can not step out for frivolous matters. |
| SmolVLM2: | on flights to and from the UK said that, |
| Qwen2.5-VL: | People can not step out for frivolous matters. |
| Ground Truth: | the process of getting something |
| SmolVLM2: | the process of getting something that you want |
| Qwen2.5-VL: | acquisition noun |

Table 11: Translation examples from test set of **iSign** dataset, where we highlight the partial matches in blue.

## C Error Patterns in Noun Phrase

The qualitative examples in Tables 12 and 13 highlight a limitation in SmolVLM2's ability to reliably identify and preserve key noun phrases during translation. We present a few examples in the PHOENIX-2014T and OpenASL datasets, which show that the model often substituted critical entities with semantically plausible but incorrect alternatives (e.g., "rehabilitation act" → "education program", "Scandinavia" → "alps"). In some cases, like for "july" and "freitag", the entities are correctly identified, yet the model frequently misses domain-relevant constructs (e.g., legal terms, geographic regions) that are essential for meaningful interpretation. These patterns point to a broader learning challenge: SmolVLM2 generates fluent text but struggles to produce the correct entities in many cases. Gloss identification by the model should be improved to reduce such hallucinations.

| Noun Phrase | PHOENIX-2014T |
|---|---|
| Ground Truth | "skandinavien", "wolken" |
| (English Translation) | ("Scandinavia", "clouds") |
| Predicted (SmolVLM2) | "alpen", "norden", "nacht", "schnee" |
| (English Translation) | ("alps", "north", "night", "snow") |
| Ground Truth | "westen", "sonne" |
| (English Translation) | ("west", "sun") |
| Predicted (SmolVLM2) | "westen", "einzelne schauer", "nordwesten" |
| (English Translation) | ("west", "isolated showers", "northwest") |
| Ground Truth | "neunundzwanzigsten oktober", "wettervorhersage" |
| (English Translation) | ("twenty-ninth October", "weather forecast") |
| Predicted (SmolVLM2) | "fünften dezember", "wettervorhersage" |
| (English Translation) | ("fifth of December", "weather forecast") |
| Ground Truth | "nordwesten deutschlands", "ostsee" |
| (English Translation) | ("northwest Germany", "Baltic Sea") |
| Predicted (SmolVLM2) | "westen", "kurzen wetterberuhigung", "neuer tiefausläufer" |
| (English Translation) | ("west", "brief weather calm", "new low pressure system") |
| Ground Truth | "norden", "alpen", "freitag", "süden", "einzelne schauer" |
| (English Translation) | ("north", "alps", "friday", "south", "isolated showers") |
| Predicted (SmolVLM2) | "freitag", "einzelne schauer", "sonne", "längere zeit" |
| (English Translation) | ("Friday", "isolated showers", "sun", "longer period") |

Table 12: Comparison of extracted noun phrases from ground truth and SmolVLM2 predictions in the PHOENIX-2014T dataset. Matching entities are highlighted in blue.

| Noun Phrase | OpenASL |
|---|---|
| Ground Truth | "section", "suit", "rehabilitation act", "title ii", "americans", "disabilities act" |
| Predicted (SmolVLM2) | "children", "education", "program", "nad", "projects", "child", "board members" |
| Ground Truth | "issues", "demands", "city" |
| Predicted (SmolVLM2) | "conference", "hartford", "ndec", "deaf education conference" |
| Ground Truth | "employers", "state laws", "employees" |
| Predicted (SmolVLM2) | "license", "driver", "people" |
| Ground Truth | "soil" |
| Predicted (SmolVLM2) | "everything", "earth", "flowers", "thing", "mindset", "trees", "nature", "plants" |
| Ground Truth | "july", "court", "testimony" |
| Predicted (SmolVLM2) | "july", "wednesday", "plan", "board" |

Table 13: Examples from the OpenASL test set illustrating matches and mismatches between ground-truth and predicted noun phrases. Matched entities are highlighted in blue. SmolVLM2 rarely aligns correctly (e.g., "july"); frequently it hallucinates incorrect content.

## D Vocabulary Bias and Distributional Influence

Tables 14 shows some of the most frequent noun phrases in the predicted text (for the test set), and their actual frequency in the ground-truth translations (for the same test set) and in the training set. We observe that many top-predicted noun phrases, such as *süden*, *norden*, and *tag*, have higher frequencies in the predicted set than in the ground-truth test set, and they also have relatively higher frequency in the training set. Similarly, Table 15 shows the most frequent noun phrases in the ground-truth translations (in the test set), and their frequencies in the model's output, the ground-truth

test set, and in the training set. We observe the same pattern that the more frequent words in the training data were over-represented in the model's output. This is a classic example of data imbalance, which makes model training very challenging. These biases in the dataset should be addressed so that model training can be done effectively.

| Noun Phrase | Predicted Freq | Test Freq | Train Freq |
|---|---|---|---|
| es | 191 | 110 | 1419 |
| süden | 106 | 50 | 653 |
| norden | 67 | 54 | 628 |
| tag | 62 | 31 | 422 |
| uns | 48 | 37 | 331 |
| wettervorhersage | 43 | 42 | 354 |
| osten | 41 | 30 | 418 |
| sich | 40 | 70 | 822 |
| montag | 32 | 17 | 194 |
| westen | 31 | 35 | 520 |

Table 14: Top 10 noun phrases from the predicted outputs with their frequencies in the predicted, test, and training sets.

| Noun Phrase | Predicted Freq | Test Freq | Train Freq |
|---|---|---|---|
| es | 191 | 110 | 1419 |
| sich | 40 | 70 | 822 |
| norden | 67 | 54 | 628 |
| süden | 106 | 50 | 653 |
| wettervorhersage | 43 | 42 | 354 |
| uns | 48 | 37 | 331 |
| westen | 31 | 35 | 520 |
| tag | 62 | 31 | 422 |
| osten | 41 | 30 | 418 |
| samstag | 28 | 28 | 242 |

Table 15: Top 10 noun phrases from the test set along with their frequency in the predicted and training sets.

Overall, these analyses indicate that training-induced vocabulary bias significantly influenced generation quality. The model often preferred frequent but potentially irrelevant tokens, leading to degraded semantic precision. These findings underline the need for frequency-aware modeling strategies, particularly for low-resource and long-tailed sign language datasets.

## E Prompt Used

The prompts used to fine-tune both of our models, and also during inference, are present in the Table 16.

| Dataset | Prompt |
|---|---|
| DGS (PHOENIX-2014T) | Übersetzen Sie das Video in deutscher Gebärdensprache in deutschen Text (gesprochene Sprache). |
| English Translation | Translate the German Sign Language video into German text (spoken language). |
| ASL (How2Sign and OpenASL) | Translate the English sign language video into spoken text. |
| ISL (iSign) | Translate the Indian sign language video into spoken text. |

Table 16: The prompt used across different datasets, for fine-tuning and inference.

## F Computational Resources

We conducted our experiments on a workstation with Intel® Xeon® Processor ICX 6326 @ 2.9 GHz, 16 Cores, 32 Threads, 256.0 GB RAM, NVIDIA A100 GPU, CUDA Version: 12.6, and Ubuntu 22.04 operating system.