

SilVar: Speech-Driven Multimodal Model for Reasoning Visual Question Answering and Object Localization

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Abstract

Visual Language Models have demonstrated remarkable capabilities across various tasks, including visual question answering and image captioning. However, most models rely on text-based instructions, limiting their effectiveness in natural human-machine interactions. Moreover, the quality of language models primarily depends on reasoning and prompting techniques, such as chain-of-thought, which remain underexplored when using speech instructions. To address these challenges, we propose **SilVar**, an end-to-end multimodal model that leverages speech instructions for reasoning-based visual question answering. Additionally, we investigate reasoning techniques at different levels, including conversational, simple, and complex speech instructions. SilVar is built upon CLIP, Whisper, and LLaMA 3.1-8B, enabling more intuitive interactions by allowing users to provide verbal or text-based instructions. To this end, we introduce a new dataset designed to challenge models with speech-based reasoning tasks for object localization. This dataset enhances the model’s ability to process and explain visual scenes from spoken input, moving beyond simple object recognition to reasoning-based interactions. To our knowledge, SilVar is the first open-source, speech-driven VLM. We believe SilVar will inspire the next generation of multimodal reasoning models, advancing toward expert artificial general intelligence. Our code and dataset are publicly available [here](#).

1 Introduction

Visual Language Models (VLMs) have gained significant attention due to their capacity to bridge the gap between visual and textual modalities, facilitating more intuitive interactions between humans and machines. These models are valuable in tasks like visual question answering (VQA), which may involve yes/no answers, multiple-choice questions, or even generating image descriptions. With advances in deep learning, VLMs can now effectively

handle visual scenes and provide meaningful textual outputs that explain or describe those scenes in natural language.

Recent advancements in VLMs, such as CLIP (Radford et al., 2021), have enabled Large Language Models (LLMs) to process images and text simultaneously (Ranasinghe and Ryoo, 2023; Alayrac et al., 2022; Awadalla et al., 2023). Models like Flamingo (Alayrac et al., 2022), BLIP-2 (Li et al., 2023b), LLaVA (Liu et al., 2023), LocVLM (Ranasinghe et al., 2024), and LISA (Lai et al., 2024) demonstrate strong multimodal capabilities, excelling in tasks such as image captioning and VQA through improved reasoning and prompting techniques. Despite these advances, most VLMs still rely on text-based interactions, limiting usability in scenarios where text is impractical. While prompting and reasoning for LLMs have been studied extensively in text, their adaptation to speech remains underexplored. Recent models like GPT-4o (OpenAI, 2024b) support speech-based interaction, greatly enhancing user experience, but open-source efforts in this area are still limited.

To enable speech interaction with LLMs, speech instruction models such as Qwen2-Audio (Chu et al., 2024), SALMONN (Tang et al., 2023), and Llama-Omni (Fang et al., 2024) have been developed to process speech instead of text-based instructions. Although these models enable speech instruction, they are not capable of understanding both images and text simultaneously. Inspired by VLMs and ARS models, we propose SilVar, a multimodal model that can understand both images and audio or images and text, at the same time. In addition, we investigate reasoning techniques for speech instructions on image description and object localization. To this end, we further provide a dataset for speech instruction. The key contributions of our paper are summarized as follows:

- We propose a multimodal model with speech

instruction for text generation and object localization.

- Speech reasoning – we investigate the effect of reasoning for speech instruction, which includes conversation level, simple reasoning, and complex reasoning.
- We propose a training pipeline and publicly release the reasoning speech instruction dataset.

2 Related Work

With the advent of large language models (LLMs) like GPT-3 (Brown, 2020), GPT-4 (Achiam et al., 2023), and open-source models such as the Llama family (Touvron et al., 2023a,b; Dubey et al., 2024) and Vicuna (Zheng et al., 2023b), the foundation was laid for the development of vision-language models (VLMs). VLMs extend LLMs by enabling learning from both text and visual inputs (Li et al., 2023b), accelerating progress in multimodal modeling, particularly for integrating vision or speech with language. Early efforts like CLIP (Radford et al., 2021) and ALIGN (Jia et al., 2021) introduced frameworks for combining vision and language. Building on these, models such as Flamingo (Alayrac et al., 2022), BLIP (Liu et al., 2024), MiniGPT-v2 (Chen et al., 2023), MiniGPT-4 (Zhu et al., 2023), and LLaVA (Liu et al., 2023) advanced tasks like visual question answering and image captioning. Applications have since expanded to object detection, segmentation, and reasoning-based localization (Liu et al., 2023; Lai et al., 2024; Zhu et al., 2023; Wang et al., 2024; Ranasinghe et al., 2024). While early models emphasized scale, recent efforts focus on smaller, high-performance models and effective prompting techniques (Wei et al., 2021; Dubey et al., 2024; Li et al., 2022).

In parallel, speech recognition has emerged as a crucial area of research, particularly with the development of automatic speech recognition (ASR) systems such as Whisper (Radford et al., 2023) and Wav2Vec (Baevski et al., 2020). In addition, there are lot of work that has been done on speech-related tasks, including speech-to-text translation, speech emotion recognition (SER), and vocal sound classification (VSC) (Tang et al., 2023; Wang et al., 2023a; Ao et al., 2021). Beyond speech generation, recent models have been investigated to enhance emotion and voice interactions, such as AudioPaLM (Rubenstein et al., 2023) and LauraGPT (Du et al., 2023), fostering more natural communication. Innovations such as VALL-E (Wang et al.,

2023b) and MusicGen (Copet et al., 2024) further illustrate how audio generation can enrich text-based interactions. Furthermore, the challenge of low-resource conversational telephony speech corpora has been investigated using unsupervised learning and fine-tuning techniques of large pre-trained models (Vieting et al., 2023).

The integration of ASR with language models has led to the development of multimodal models (Chu et al., 2024; Xie and Wu, 2024). For instance, SpeechGPT (Zhang et al., 2023a) allows users to engage with large language models using speech. Additionally, HuggingGPT (Shen et al., 2024) enhances this interaction by discretizing speech into tokens and expanding the LLM’s vocabulary to accommodate speech inputs. Furthermore, the study in (Adedeji et al., 2024) demonstrated that LLMs have the potential to improve the accuracy of ASR systems, particularly in medical transcription.

While VLMs have significantly advanced vision-text integration, incorporating audio and ASR has enabled more dynamic multimodal interactions. The release of GPT-4o (OpenAI, 2024b) showcases real-time speech-based interaction with LLMs, improving user experience over text-only models. However, its closed-source nature limits further development. Currently, few open-source models support speech-based interaction with VLMs. To address this, we introduce **SilVar**, a novel multimodal model that integrates speech instructions directly into the reasoning process, enhancing tasks like image interpretation and object localization. We also provide a complete pipeline leveraging open-source foundation models, aiming to support and inspire research in multimodal reasoning.

Prompting techniques play a vital role in enhancing LLMs’ reasoning abilities for tasks like question answering (Liu et al., 2023; Lai et al., 2024), with methods such as chain-of-thought (CoT) and zero-shot prompting significantly influencing performance (Wei et al., 2022; Yao et al., 2024). In ASR contexts, prompting has also been applied to complex tasks like diarization and error correction (Adedeji et al., 2024). Building on this, we explore reasoning techniques, particularly zero-shot and CoT prompting, for speech-based instruction. As LLMs, VLMs, and instruction tuning evolve, benchmarks such as ScienceQA (Lu et al., 2022), MMMU (Yue et al., 2024), and LLaVA (Liu et al., 2023) have been developed to evaluate multimodal reasoning, yet they primarily focus on text-image input. To address the lack of benchmarks

for speech-based instruction, we introduce **SilVar**, a new dataset that incorporates text, images, and speech instructions for text generation. We also augment existing reasoning datasets like MMMU, LISA, and ScienceQA by converting their text inputs into speech.

3 Data Generation

With the development of multimodal models, there has been a surge in datasets that support model training, such as Flickr30K (Young et al., 2014), Visual Genome (Krishna et al., 2017), and MovieQA (Tapaswi et al., 2016). However, these datasets are limited to tasks like automatic image description, image or video captioning, and simple visual question-answering. To explore the understanding and explainability of multimodal models, more intricate datasets such as LAION (Schuhmann et al., 2022), SEED (Li et al., 2023a), and LLaVA (Liu et al., 2023) have been created, enabling LLMs to generate detailed responses. Despite this progress, the available data are insufficient for guiding LLMs in querying and responding to users' input, particularly for tasks requiring complex instructions. As a result, techniques like hard prompting (Wen et al., 2024) or prompt engineering (Wei et al., 2022; Yao et al., 2024) have been proposed. For dataset, LLaVA (Liu et al., 2023) is one of the recent datasets that use strong prompting baselines. However, this type of data is a text-based instruction and not well-suited for speech instruction, especially in the context of human-machine interaction. For this, we propose a unique speech instruction dataset that emphasizes natural conversation.

Inspired by the success of recent GPT models in text-based tasks and GPT-assisted datasets (Liu et al., 2023), we developed our dataset with GPT-4 (OpenAI, 2024a) assistance, as shown in Figure 1. Notably, we only used text as input for GPT-4 to generate different types of questions. To ensure the model can effectively perform reasoning-based object localization and generate coherent responses from speech instructions, we designed the dataset according to the following criteria:

- **Human-machine conversation:** The dataset is designed to reflect natural human-machine conversations, enabling the agent to interpret and respond to verbal instructions in a conversational context.
- **Reasoning instructions and responses:** Unlike traditional datasets focused on simple ob-

ject recognition, our dataset contains reasoning instructions and explanations behind the responses. This is crucial for enhancing the model's ability to explain not just what the object is, but also why it is located in a particular place.

- **Detailed descriptions:** The dataset includes both simple questions and complex reasoning scenarios, requiring the model to provide detailed descriptions of visual scenes.

The SilVar dataset contains 4,161 speech-driven samples based on 2,518 randomly selected images from the COCO 2014 dataset (Lin et al., 2014). It includes two task types: spatial object localization (2,361 samples), which helps models learn spatial reasoning, and object detection with bounding boxes (1,800 samples), the primary focus of this work. All samples are generated using GPT-4 with a structured prompting strategy. For spatial tasks, object positions are described using directional terms (e.g., left, right, front, behind), while detection tasks include bounding box outputs. Rather than naming objects directly, GPT-4 generates scenario-based questions that highlight an object's role, as illustrated in Figure 1, with answers providing detailed explanations.

- **Object's characteristics:** A description of the object's features, shape, and functionality.
- **Background context:** An explanation of how the object is relevant to the broader environment depicted in the image.
- **Interaction with surroundings:** An analysis of how the object interacts with other elements in the scene, such as people, activities, or other objects.

Following the generation of questions and answers, four people corrected the data to ensure quality and coherence. Human reviewers verified that each set of questions consistently referred to the same object and that the answers offered detailed reasoning, including the object's characteristics, background, and interactions. In addition, bounding boxes were manually labeled using Roboflow (Dwyer et al., 2024) to accurately pinpoint the specific objects being referred to in each image. After ensuring data quality through human verification, we convert text to speech using Google Cloud APIs,

Question type 1: Conversation

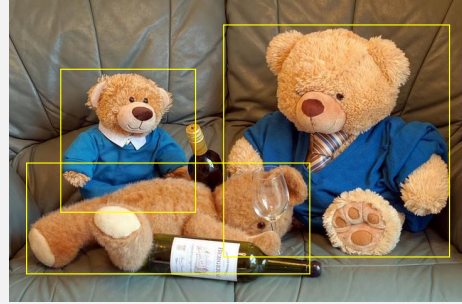
What object known for its comfort and joy, often in colorful outfits, is frequently found in cozy gatherings? Let's explain it in detail.

Question type 2: Simple reasoning

What object known for comfort and joy, often in colorful outfits, is frequently found in cozy gatherings? Let's think step by step.

Question type 3: Complex reasoning

As friends come together for a laid-back evening of sharing stories and enjoying refreshments, what soft and cuddly figure symbolizes friendship and nostalgia, often bringing a smile to those in its presence?

**Response:**

The soft and cuddly figure referred to is the teddy bear, located at [BBOX]. This plush toy evokes feelings of nostalgia and friendship, characterized by its rounded form, soft fur, and friendly expression. Its placement among friends and the wine bottles signifies its role in creating a warm and inviting atmosphere, where stories can be shared. The bear's presence encourages a sense of camaraderie and emotional connection among guests, reinforcing how such objects often serve to bridge interactions and enhance the joy of gathering.

BBOX: [[304,36, 628, 364], [28, 230, 423, 384], [76, 96, 258, 292]]

Figure 1: An example from our SilVar-bench dataset, focusing on reasoning speech instructions with different types: conversation, simple reasoning, and complex reasoning. The detected objects are highlighted in yellow bounding boxes. The dataset not only focuses on reasoning instructions but also generates visual explanations, enhancing spatial understanding and interpretability.

which support over 50 voices. SilVar-Bench provides a robust evaluation framework, challenging models in object recognition and context-specific reasoning. It is designed to advance multimodal models requiring spatial understanding and detailed reasoning in speech-driven interactions. It is worth noting that our dataset is larger than smaller-scale datasets such as LISA, which contains only 1,218 samples. This highlights that our dataset ensures not only quality but also sufficient quantity.

Dataset	Train	Validation	Test
ScienceQA	6,218	2,097	2,017
MMMU	150	900	10,500
LISA	239	200	779
SilVar	3,461	-	700

Table 1: The datasets used in this study. It is important to note that the SilVar training set contains 1,100 bounding box localization samples and 2,361 spatial localization samples, while the test set includes 700 bounding box localization samples.

In addition to our dataset, we utilize existing text-based reasoning datasets—MMMU (Yue et al., 2024), LISA (Lai et al., 2024), and ScienceQA (Lu et al., 2022)—for pretraining, as they focus on reasoning, localization, and description. MMMU includes 11,500 samples across 30 subjects and 183 subfields, while LISA provides 239 training samples (we use only the training split). ScienceQA

spans 26 topics, 127 categories, and 379 skills; we filter it to include only samples with image-text pairs. To adapt these datasets for spoken input, we apply preprocessing steps to ensure clarity and vocalizability for speech generation.

- **Handling special characters:** We converted complex symbols like LaTeX and non-standard characters into formats suitable for speech instruction, enabling correct processing and vocalization.
- **Punctuation and text normalization:** We standardized punctuation in the text to ensure that it would generate smooth, natural speech outputs, enhancing the clarity and coherence of the spoken content.

4 Speech-Driven Visual Language Model

4.1 Architecture

SilVar is a multimodal model designed for image interpretation and object localization based on various input modalities, including speech and text. This approach enables SilVar to understand and respond comprehensively to various inputs and prompts. The model architecture is illustrated in Figure 2, consisting of several key components: an audio encoder, a visual encoder, a projector, and a large language model.

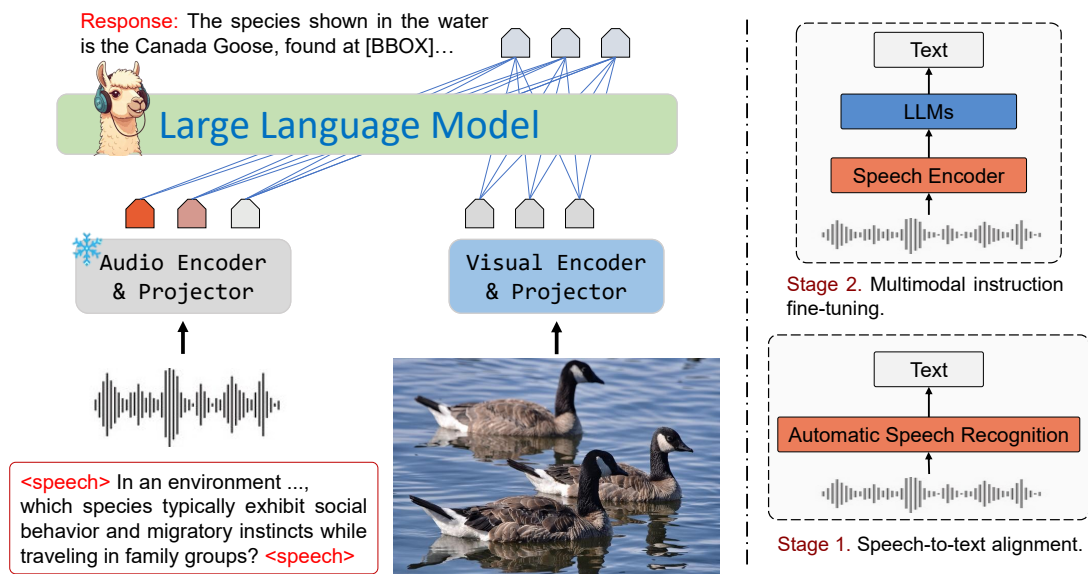


Figure 2: Illustration of the SilVar’s architecture, integrating images and audio instruction for reasoning description and object localization.

Audio Encoder: This module extracts features from speech instructions to provide context beyond text-based inputs. We use the lightweight Whisper-tiny model (Radford et al., 2023; Moor et al., 2023), with 39M parameters, known for its strong performance in speech recognition. Given an input audio $\$A\$$ (max length 1500), Whisper encodes it into a 768-dimensional feature vector. This is passed through a Linear layer (audio projector) to match the LLM input size (\mathbb{R}^{4096}) and is later concatenated with image embeddings. We also explore different audio adapters, including MLP and Transformer layers.

Visual Encoder: This module extracts meaningful features from input images using the pre-trained CLIP model (ViT-B/32) (Radford et al., 2021), which was trained on over 400 million image-text pairs. For each image $X \in \mathbb{R}^{H \times W \times C}$, where $C = 3$, the input is resized to 224×224 and passed through CLIP to produce a sequence of 768-dimensional visual tokens. To align with the language model, these tokens are projected to \mathbb{R}^{4096} using a visual adapter. Following MiniGPT-v2 (Zhu et al., 2023), the adapter consists of two Linear layers with GELU activation. The resulting visual features are concatenated with audio embeddings to form a unified multimodal representation.

Large Language Model: At the core of SilVar is a language model, responsible for generating text and bounding boxes by processing information from the audio and visual encoders. To this end,

we decided to use LLama 3.1-8B (Dubey et al., 2024), which serves as the foundational model, allowing us to effectively transfer its pre-trained knowledge into domain-specific tasks such as localization where understanding both verbal and visual inputs. By combining visual and audio tokens, we provide a diverse set of token embeddings for the language model, requiring it to process and generate a final representation of textual tokens. The integration of these components enables SilVar to generate human-quality text responses by leveraging the complementary strengths of each modality, making it a robust system for multimodal instruction and interaction.

4.2 Training Pipeline

We propose a two-step training process for speech instruction: (1) speech-to-text alignment and (2) LLM training response, as shown in Figure 2. Since speech plays an important role as an instructional modality in our model, we start training a speech-to-text system to align audio with text in the domain of reasoning text generation. We use the Whisper models for speech recognition due to their efficiency in real-time speech processing. As mentioned in Section 4.1, to develop a foundation model that can understand and handle numerous tasks, we train the model on the ScienceQA and MMMU datasets using speech instructions, as these datasets are reasoning benchmarks for human-level understanding and explanation (Lu et al., 2022; Yue et al., 2024). Furthermore, we

aim to specialize the model for the task of object localization; therefore, we further train the Whisper on the LISA dataset and our benchmark. The data type of each dataset and the stages used in the training process are shown in Table 2.

Dataset	Data type	Stage 1	Stage 2
ScienceQA	Text, image	x	x
MMMU	Text, image	x	x
LISA	Text, image	x	x
SilVar	Text, image, speech	x	x

Table 2: Summary of datasets and corresponding stages used in our training process.

In stage 2, we use the pre-trained weights from stage 1 to train our model for the visual question-answering task, using direct audio input from the audio encoder for reasoning. Similar to stage 1, we use the ScienceQA, MMMU, LISA, and SilVar datasets for training text generation. In our experiments, we use AdamW optimizer to update the parameters (Loshchilov and Hutter, 2019), accompanied by a learning rate scheduler with a linear warmup followed by a cosine decay. The model is trained for up to 20 epochs with a batch size of 4 and 2 workers. The model is trained on a computing system equipped with four A100 GPUs, around twenty-two hours.

5 Experiment and Result

5.1 Speech To Text Alignment and Quality

We trained Whisper for 10 epochs on converted-to-speech datasets, and the results are shown in Table 3 using WER and CER metrics. While Whisper Tiny performs well overall, its accuracy varies across datasets. For example, ScienceQA exhibits higher error rates (WER: 7.77 train, 7.98 test), with Whisper Small significantly outperforming it. Despite minor misalignments affecting embeddings and final predictions, we chose Whisper Tiny due to its compact size and suitability for our end-to-end training process later.

Dataset	Models	WER		CER	
		train	test	train	test
ScienceQA	Whis. Small	4.30	4.17	5.25	4.32
ScienceQA	Whis. Tiny	7.77	7.98	9.43	10.21
MMMU	Whis. Tiny	6.45	6.72	5.18	5.76
SilVar	Whis. Tiny	2.16	3.58	2.59	3.54

Table 3: Evaluation of speech-to-text alignment of audio encoders. Whis. denotes Whisper.

5.2 Speech Instruction & Text Instruction

To evaluate the impact of instructional modality, we compare SilVar’s performance using speech- and text-based instructions across various reasoning and conversational tasks. This includes assessing its ability to handle both simple and complex reasoning, as well as conversational prompts, in both formats. SilVar is trained only on complex reasoning, while other techniques are used for evaluation. We use CIDEr, BLEU, METEOR, and ROUGE for text generation, and bounding box accuracy at an IoU threshold of 0.5 for object localization, providing a comprehensive performance overview.

As shown in Table 4, text-based instructions consistently outperform speech-based ones across most metrics, with complex reasoning achieving the highest scores: ROUGE-1 (37.23), BLEU-1 (38.12), METEOR (28.66), and CIDEr (0.08). In object detection, the IoU0.5 accuracy reaches 27.56% for text-based complex reasoning, indicating better localization. Speech-based inputs also perform best with complex reasoning but score slightly lower. These results highlight SilVar’s effectiveness and the challenges of aligning synthetic speech with images, as discussed in Section 5.1.

5.3 MMMU-bench

MMMU is a benchmark with tasks that demand college-level knowledge and deliberate reasoning, which enables the test of model performance in terms of expert-level perception and reasoning. The dataset includes 30 subjects across various disciplines, such as art, science, and engineering. In particular, we compare the SilVar to models that have similar number of parameters.

As shown in Table 5, our text-based model achieves a validation score of 31.8, outperforming several similarly sized baselines, including Adept Fuyu-8B (27.9), OpenFlamingo2-9B (28.7), MiniGPT4-Vicuna-13B (26.8), and LLaMA-Adapter2-7B (29.8), demonstrating strong performance in complex reasoning. While it trails behind SOTA models like LLaVA-1.5-13B (36.4), it offers a solid balance of accuracy and efficiency. With speech-based instructions, SilVar also performs well, scoring 30.2, which is better than using pure transcribed text from Whisper (30.0), and showcasing its multimodal versatility. End-to-end training further improves performance to 30.4. Replacing Llama3.1 with DeepSeek-R1-Distill-Llama-8B boosts the score to 32.8. Al-

Instruction Type	ROUGE-1	BLEU-1	METEOR	CIDEr	Accuracy (IoU = 0.5)
Complex reasoning (text)	37.23	38.12	28.66	0.08	27.56
Simple reasoning (text)	34.08	36.11	27.58	0.07	26.54
Conversation (text)	35.15	36.57	26.95	0.07	26.56
Complex reasoning (speech)	34.44	37.62	26.99	0.06	24.44
Simple reasoning (speech)	33.42	34.83	24.74	0.05	23.02
Conversation (speech)	34.16	34.25	23.86	0.04	22.71
<i>Ablation study when using DeepSeek-R1-Distill-Llama-8B as the language model</i>					
Complex reasoning (speech)	38.62	39.05	28.17	0.09	28.41

Table 4: Performance of SilVar model on various instructional types (conversational, simple, and complex) using speech- and text-based modalities. The highlighted values in purple represent the highest scores achieved for each metric in text-based complex reasoning, while values in orange highlight the highest scores for speech-based complex reasoning.

Model	Instruction	Val	Test
LLaVA-1.5-13B (Liu et al., 2024)	Text	36.4	33.6
Qwen-VL-7B-Chat (Bai et al., 2023)	Text	35.9	32.9
LLaMA-Adapter2-7B(Zhang et al., 2023b)	Text	29.8	27.7
OpenFlamingo2-9B (Awadalla et al., 2023)	Text	28.7	26.3
Adept Fuyu-8B (Bavishi et al., 2023)	Text	27.9	27.4
MiniGPT4-Vicuna-13B (Zhu et al., 2023)	Text	26.8	27.6
<i>Our experiments</i>			
SilVar	Text	31.8	-
SilVar-transcribed	Text	30.0	-
SilVar	Speech	30.2	-
SilVar-e2e	Speech	30.4	-
GPT-4o mini	Speech	39.3	-
Gemini Flash 1.5	Speech	36.9	-
<i>Ablation study when using DeepSeek as the language model</i>			
SilVar-e2e (DeepSeek)	Speech	32.8	-

Table 5: Performance of SilVar and other models on the MMMU benchmark. e2e denotes end-to-end training, and transcribed denotes the usage of Whisper-transcribed text.

though GPT-4o mini (39.3) and Gemini Flash 1.5 (36.9) achieve higher scores, SilVar shows strong potential as an open-source, speech-driven VLM suitable for fine-tuning on downstream tasks.

5.4 ScienceQA Benchmark

In this benchmark, we compare SilVar to SoTA models with a similar parameter count, using both speech- and text-based instructions. As shown in Table 6, text-based SilVar achieves an average accuracy of 86.32, outperforming models like LLaMA-Adapter (85.19) and approaching Chat-UniVi (88.78). Speech-based SilVar scores 63.21%, surpassing several text-instruction models, including MiniGPT-4 (47.71), LLaVA-7B (41.10), and OpenFlamingo (39.27). End-to-end training yields a slight improvement, and replacing the language model with DeepSeek-R1-Distill-Llama-8B raises the score to 65.82. We also compare SilVar to speech-driven GPT-4o mini (80.15) and Gemini

Flash 1.5 (78.31). While a performance gap remains between speech- and text-based models, SilVar proves competitive and promising in scenarios where spoken instructions are necessary.

5.5 Chatbot models

After training SilVar, we evaluated its performance by comparing its predictions with those of commercialized chatbots such as GPT-4o mini and Gemini Flash 1.5. As shown in Table 8, all three models successfully inferred the underlying activity in the image. SilVar demonstrated an enriched reasoning process by incorporating both speech and spatial awareness. This highlights SilVar’s ability and potential in VQA tasks and enables us to fine-tune it for downstream applications. Furthermore, this capability suggests that SilVar can effectively integrate visual and auditory information in an end-to-end manner, making it particularly suited for vision-language tasks that require speech commu-

Model	Instruction	Average Score
LLaVA-13B (Liu et al., 2023)	Text	90.92
LaVIN-13B (Luo et al., 2024)	Text	90.83
Chat-UniVi (7B) (Jin et al., 2024)	Text	88.78
LLaMA-Adapter (Zhang et al., 2023b)	Text	85.19
MiniGPT-4 (Zheng et al., 2023a)	Text	47.71
LLaVA-7B (Yang et al., 2023)	Text	41.10
OpenFlamingo (Yang et al., 2023)	Text	39.27
<i>Our experiments</i>		
SilVar	Text	86.32
SilVar	Speech	63.21
SilVar-e2e	Speech	63.45
GPT-4o mini	Speech	80.15
Gemini Flash 1.5	Speech	78.31
<i>Ablation study when using DeepSeek as the language model</i>		
SilVar-e2e (DeepSeek)	Speech	65.82

Table 6: Performance comparison of our model and other models on the ScienceQA Benchmark. e2e denotes end-to-end training.

nication like medical surgery and self-driving cars.

6 Ablation study

While visual and audio encoders are key to processing image-speech pair instructions, the visual and audio adapters are equally vital for transferring encoded information to LLMs. In Llava (Liu et al., 2024), linear and MLP-based adapters effectively bridge encoders and LLMs. Model performance can also benefit from different neural network types (Chen et al., 2020b,a), and adapter choice is critical in multimodal models like the Q-Former in BLIP-2 (Li et al., 2023b) and the Perceiver Resampler in Flamingo (Alayrac et al., 2022). Building on this, we design both MLP- and Transformer-based adapters for the audio encoder.

Table 7 shows SilVar’s performance using different audio adapters in end-to-end speech instruction training. The Transformer-based adapter requires 1.5× more training time than the MLP-based one. However, performance differences are minimal, suggesting that using Whisper’s final encoder layer eliminates the need for complex adapter designs. We also explore different MLP hidden layer sizes (2816 and 5632), finding performance variation within ± 0.1 on the MMMU dataset.

Adapter	SilVar	MMMU (val)	ScienceQA
Linear layer	24.44	30.04	63.45
MLP	25.17	31.16	63.41
Transformer	25.66	31.05	63.78

Table 7: Performance of SilVar with different audio adapters on VLM benchmarks.

Additionally, we replace Llama 3.1 with DeepSeek-R1-Distill-Llama-8B, resulting in modest gains, about 8% on MMMU and 4% on ScienceQA, as shown in Table 4, Table 5, and Table 6.

7 Conclusion

In this study, we present **SilVar**, the first end-to-end speech-driven VLM designed to enhance human-machine interaction by enabling effective reasoning from both images and speech instructions. Unlike most existing VLMs and LLMs that depend on text inputs, SilVar is an open-source model supporting verbal communication, allowing for more intuitive and natural interactions. However, building speech-based VLMs is challenging due to input quality and the alignment of audio and visual embeddings, leading to a performance gap compared to text-based models. However, SilVar performs comparably to text-based VLMs on the MMMU and ScienceQA benchmarks, showing its potential in scenarios where text input is unavailable.

Limitations

One limitation of this work is the small size of the training dataset. Despite it being enough to fine-tune our model for the new task, the usage of this dataset outside of our research scope could be limited.

Potential risks

The core of Silvar is a pre-trained LLM, which can suffer from hallucination and sometimes produce incorrect information. The usage of this model should be carefully revised in Silvar’s answer.

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A Chatbot Comparison

Question: What activity might be taking place that encourages interaction and bonding between the two individuals in the image?

Silvar: The two individuals share a playful moment and joy, they are located [142 459 284 359]. In the environment like a zoo, they might be engaging in an interactive activity like visiting the zoo or feeding animals. This activity may enhance their experience through shared laughter and companionship.

GPT-4o mini: The two young children in the image appear to be at a zoo, standing in front of a giraffe enclosure. They are holding hands, smiling, and leaning close to each other, suggesting a shared moment of enjoyment. The activity that might be encouraging interaction and bonding between them is a visit to the zoo, where they are likely exploring and experiencing animals together. This shared experience fosters a sense of excitement, curiosity, and connection.

Gemini 1.5 Flash: The two individuals in the image are encouraged to visit a zoo or animal park together. Observing and reacting to the animals fosters interaction and bonding through shared experience, communication, and physical closeness.

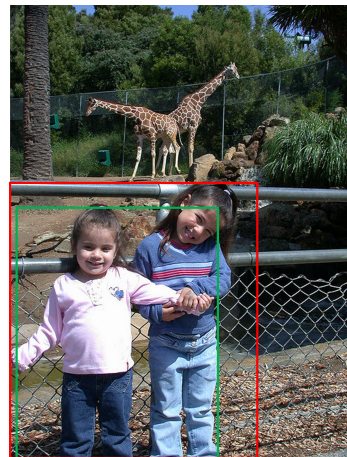


Table 8: Comparison of predictions between our models and the other speech-driven model on the reasoning abnormal detection. Unlike GPT-4o mini and Gemini 1.5 Flash, our Silvar is an open-sourced end-to-end speech-driven VLM.