Multimodal Perception and Comprehension of Corner Cases in Autonomous Driving

電機碩二 R12921057 林佳儀, 電機碩二 R12921125 楊沛蓉, 電機碩一 R13921093 李彥璋, 網媒碩二 R12944030 簡志宇

Panda603

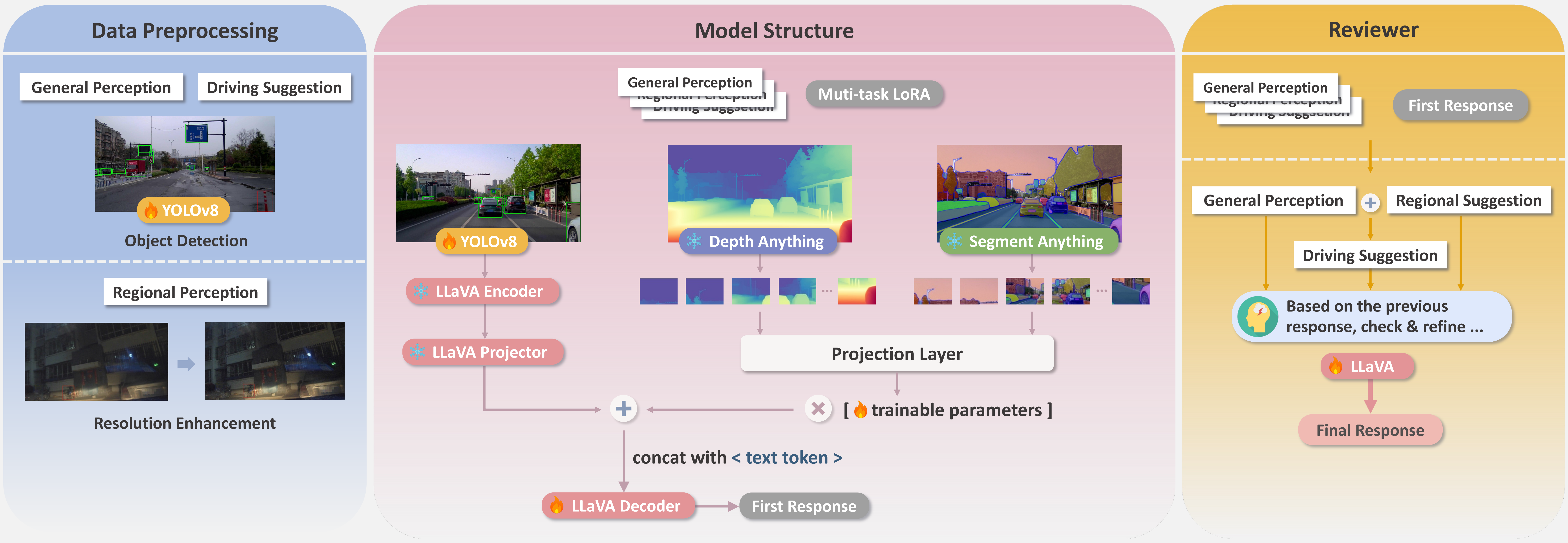
Abstract

Real-world traffic scenarios pose significant challenges for Visual Language Models (VLMs) like LLaVa, particularly in detecting small objects and handling complex traffic interactions. To address these limitations, we enhance LLaVa-1.5-7b through an optimized three-stage preprocessing pipeline. First, we integrate YOLO-based detection with resolution enhancement techniques to improve image quality and object recognition. Second, we enhance the model's perception through a multi-task learning framework that integrates depth and segmentation information using LoRA-based adaptation. Finally, we implement a specialized validation module to refine and verify model responses. Our enhanced system demonstrates superior performance in global scene understanding, object detection accuracy, and contextual reasoning for autonomous driving scenarios.

Ablation Study

- **LoRA Rank Effects (8-64)**: We observed that higher ranks showed decreased performance under constant training time. Extended training periods led to overfitting issues, significantly reducing the model's ability to generalize to new scenarios.
- **Handling Missed Scene Factors**: The model initially missed critical scene elements like traffic cones. Integration of *Recognize Anything* for automated tagging of important scene factors during inference significantly improved contextual understanding.
- **Reviewer Module Findings**: The reviewer let the model revisit images to refine its initial response. Interestingly, we found that using a model with lower testing score to train the reviewer resulted in better refinement ability compared to a higher-scoring one. We hypothesize that this is due to lower-scoring models developing stronger revising capabilities by learning to transform low-quality responses into high-quality ones.

Method



Data Preprocessing

General Perception
Driving Suggestion
🔥 YOLOv8
Object Detection

Regional Perception
Resolution Enhancement

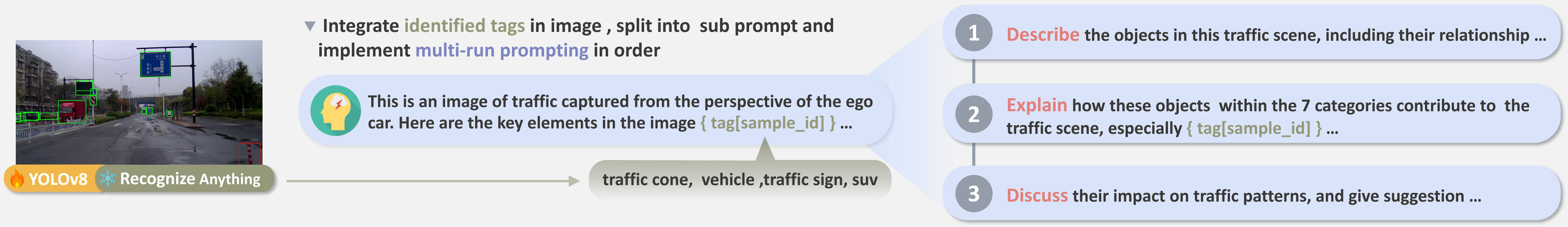
Model Structure

General Perception
Regional Perception
Driving Suggestion
Muti-task LoRA
🔥 YOLOv8
Depth Anything
Segment Anything
LLaVA Encoder
LLaVA Projector
Projection Layer
[🔥 trainable parameters]
concat with < text token >
🔥 LLaVA Decoder
First Response

Reviewer

General Perception
Regional Perception
Driving Suggestion
First Response
General Perception
Regional Suggestion
Driving Suggestion
Based on the previous response, check & refine ...
🔥 LLaVA
Final Response

Prompting Mechanism Design



▼ Integrate identified tags in image , split into sub prompt and implement multi-run prompting in order

🔥 YOLOv8 Recognize Anything

This is an image of traffic captured from the perspective of the ego car. Here are the key elements in the image { tag[sample_id] } ...

traffic cone, vehicle ,traffic sign, suv

1 Describe the objects in this traffic scene, including their relationship ...

2 Explain how these objects within the 7 categories contribute to the traffic scene, especially { tag[sample_id] } ...

3 Discuss their impact on traffic patterns, and give suggestion ...

Experiment

Setting	Gemini Score
LLaVA	2.856
Finetuned LLaVA (Multi-Task LoRA)	3.841
w/ YOLOv8	
w/ Depth & Segmentaion map	
w/ Reviewer (Pure LLaVA)	3.921
w/ Reviewer (Finetuned LLaVA)	
Combine All	

Our three-stage approach significantly improves LLaVa's performance, with the combined method achieving a 46% increase in Gemini score (from 2.856 to 4.173) through enhanced Perception and reviewing process.

Conclusion

Our proposed framework integrates several advanced components, These innovations collectively contribute to our successful results in our metric. Key highlights include:

- **YOLO-based Image Detection**: Finetuned YOLO to enhance small object detection and recognition.
- **Resolution Enhancement**: Improved image quality to support accurate visual processing.
- **Multi-Task Perception Enhancement**:
  - *Depth Anything* for depth estimation and spatial understanding.
  - *Segment Anything* for precise object and region segmentation.
  - *Recognize Anything* for robust object and feature identification.
  - **Lora-based Adaption**: Efficient fine-tuning of LLaVa-1.5-7b for seamless integration of multi-modal information.