Traffic-Sign Detection and Recognition for Autonomous Vehicles Applications

A Proposal Prepared for the

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CS329: Machine Learning(H)

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Abstract

Traffic sign recognition and detection constitute vital components of autonomous driving and advanced driver-assistance systems. Despite the integration of most signs into electronic maps, challenges persist, including outdated information and temporary signs. Therefore, the recognition of signs using in-vehicle cameras remains indispensable.

This project reviews existing datasets, recognition models, and the merits and drawbacks of various recognition methods. It aims to enhance the field by proposing methodologies to improve an existing model, thereby addressing the challenges associated with timely updates and the identification of temporary signs.

1. *Background*

1.1. Traffic Sign Detection

Traffic sign detection is a critical component in autonomous vehicle driving systems. The evolution of this field has seen a shift from traditional machine learning methods and template matching to more advanced deep learning techniques, driven by the advent of high-performance computers and the explosion in data volume.

1.2. Previous Work for Detection and Recognition

Early recognition methods in traffic sign recognition used a sliding window strategy to traverse the entire image and generate many candidate regions. The candidate regions were then extracted with various types of hand-designed features, such as HOG (histogram of oriented gradient), SIFT (scale-invariant feature transform), and LBP (local binary pattern). These features were then fed into an efficient classifier, such as SVM (support vector machine), Adaboost, or Random Forest, for detection and identification. However, traditional target detection methods are not robust to changes in diversity, and sliding window-based region selection is not targeted and time-consuming.

The emergence of deep-learning techniques introduced significant advancements in traffic sign detection. Unlike traditional methods, deep-learning models automatically extract features, eliminating the limitations of manual feature extraction, and exhibit high generalizability and robustness. Two predominant types of CNN-based target detection algorithms are single-stage detectors based on regression and two-stage detectors based on candidate areas.

For instance, Zuo et al. implemented the two-stage Faster R-CNN algorithm, employing conditional scanning, candidate box generation, feature extraction, and classification for traffic sign detection. Li et al. utilized Faster R-CNN and MobileNet structures for localization refinement, incorporating color and shape information. They demonstrated successful detection of various traffic signs. In contrast, single-stage target detection algorithms, such as SSD and YOLOv8, use clustering algorithms to create prior boxes, accelerating real-time detection.

In summary, deep learning-based detection methods enhance the ability of intelligent vehicles to detect traffic signs in complex road scenarios. The demand for real-time and accurate traffic sign detection has increased with the rapid development of intelligent vehicles. This project proposal adopts a single-stage deep learning detection approach to further contribute to the field.

2. *Motivations*

Recognizing traffic signs is a pivotal aspect of intelligent vehicle driving systems. While traffic sign recognition tasks typically unfold in natural scenes, various weather conditions such as rain, snow, or fog can obscure the information conveyed by these signs. Moreover, issues like overexposure and low light conditions tend to diminish the visibility of traffic signs. Besides, the continuous exposure of traffic signs throughout the year may lead to fading, obscurity, or damage to their surfaces.

The dynamism of complex environments poses a significant impact on the speed and accuracy of traffic sign recognition for intelligent transportation. Consequently, there is an urgent need to delve into the intricacies of fast and accurate traffic sign detection, particularly in the face of challenging and multifaceted environments.

Moreover, there is still room for improvement, particularly in the area of real-time detection. Single-stage target detection algorithms, such as YOLOv8, have shown great potential in this regard, but further research and development are needed to optimize its performance.

This project is driven by the desire to contribute to this field of study, with the aim of developing a single-stage deep learning detection approach that can enhance the real-time and accurate detection of traffic signs.

This will not only contribute to the advancement of autonomous vehicle technology but also to the broader goal of improving road safety and efficiency.

3. *Related Work*

3.1. YOLOv8

Ultralytics YOLOv8, developed by Ultralytics, is a cutting-edge, state-of-the-art (SOTA) model that builds upon the success of previous YOLO versions and introduces new features and improvements to further boost performance and flexibility. YOLOv8 is designed to be fast, accurate, and easy to use, making it an excellent choice for a wide range of object detection, image segmentation and image classification tasks.

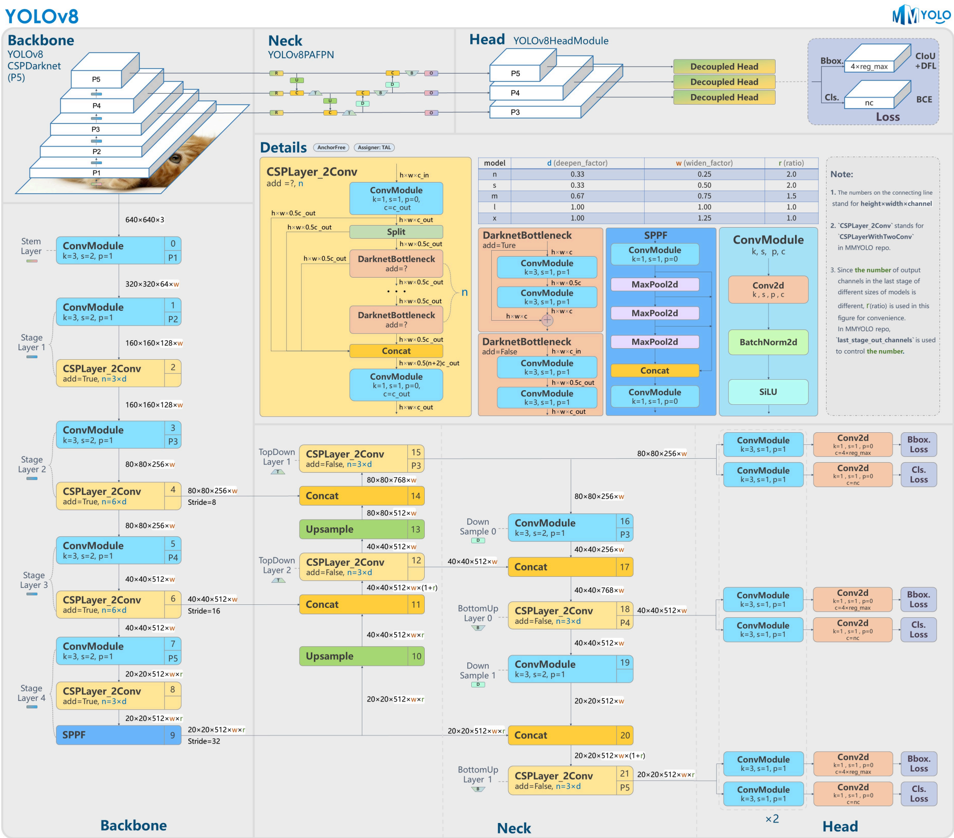


Figure 1: YOLOv8-P5 model structure

4. *Novelty of This Work*

In this project, we try to improve the state-of-the-art YOLOv8 through various methods and apply the refined model to traffic sign detection and recognition tasks, then compare the performance with the vanilla YOLOv8.

5. *Methodology*

5.1. Dataset Preprocessing

The dataset used for training, validating and testing is Tsinghua-Tencent 100K Annotations 2021. Dataset and preprocessing TT100K(Tsinghua-Tencent 100K) is a dataset which contains 100000 Tencent Street View panoramas, including large variations in illuminance and weather conditions in China. All of the traffic-sign in the pictures is annotated in a json-format file with a special class label, which marks the center of a box containing traffic-signs and also the normalized width and height.

Figure 2: A Sample from TT1000K Dataset

```
"8169": {
    "path": "test/8169.jpg",
    "id": 8169,
    "objects": [
        {
        "bbox": {
        "xmin": 871.2, "ymin": 608.8,
        "xmax": 928.8, "ymax": 665.6
            },
            "category": "il100"
        },//...
```

Traffic Sign Label in JSON

6. *Resource and Experiment Platform*

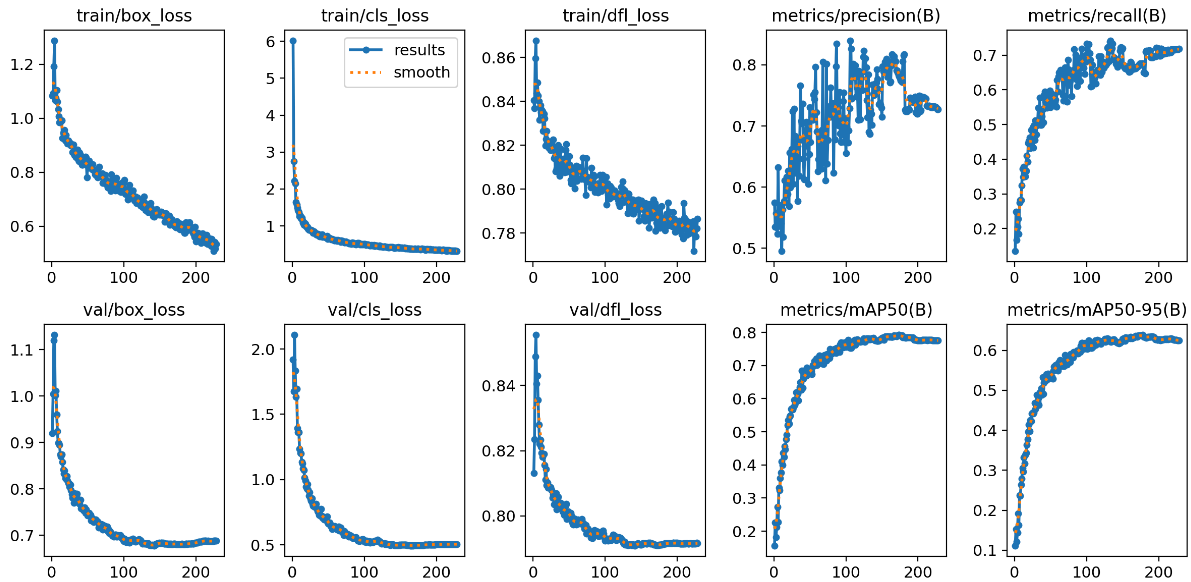
GPULab02 Server for Teaching in Dept.CSE

Intel(R) Xeon(R) Gold 6240 CPU @ 2.60GHz

7. *Initial Results*

We have collected some data inside campus, both day and night, including multiple different signs.

For training part, the result for 228 epoch yolov8x is as follow:



We can see that the precision part is not stable.

And we test this model on some samples:

Figure 3: Recognition Result on Wild Dataset by YOLOv8x

8. *Goals and Objectives*

8.1. Task 1: Problem Formulation

The first step involves an extensive literature review to identify existing models, datasets, and benchmarking methodologies related to Traffic-Sign Detection and Recognition. This review will provide a foundation for understanding the state-of-the-art techniques, strengths, and weaknesses of different approaches.

After understanding the detection and recognition tasks, do problem formulations and definitions …

8.2. Task 2: Model Selection and Justification

Select some models and detasets from literature review step, and operate training, validating and testing using various models for traffic-sign detection and recognition over multiple datasets. Select a suitable deep neural network architecture for this task, and fine tune the model to obtain better performance.

8.3. Task 3: Model Performance Evaluation

First, we will define appropriate metrics for evaluating the trained model according to related works, like accuracy, precision, speed etc. These metrics will serve as quantitative indicators of the model's effectiveness in recognizing and detecting traffic signs.

Evaluate the performances of the trained models with several metrics like model complexity, computational efficiency, robustness etc. Compare the performances of different models over different datasets. Summary and explain the pros and cons of different models.

Also, Collect a custom dataset of traffic signal detection and recognition scenarios. The selected model will be tested on custom real-world traffic sign images or video streams to assess its robustness and reliability.

8.4. Task 4: Model Fine-Tuning (Optional)

Construct the trade-off model of the selected optimal model, then fine tune the model on the chosen dataset such as hyperparameter tuning, loss functions, and regularization techniques.

And we will explain the way in which the model is fine-tuned, and, if explanable, why it is fine-tuned in this way. Ultimately, this project is expected to produce a model with the best performance evaluation for the task of traffic signal detection and recognition, and to give some suggestions and explanations for model fine-tuning.

9. *Project Scheduling*

9.1. *Staffing Plan*

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- Literature review
- documentation
- datasets selection
- model training and evaluation
- custom dataset collection

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- Literature review
- benchmark building
- model selection
- model training and evaluation
- custom dataset collection

9.2. *Timeline*

Week 8 - 10

- Project Proposal
- Literature Review
- Environment configuration

Week 11 - 13

- Dataset preparation
- Model training, validating, testing
- Model evaluation, comparasion and selection

Week 14 - 15

- Shoot custom datasets
- Evaluate the optimal model using custom datasets
- Summary and Conclusion

Further development

- Fine tuning the optimal model

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