Traffic Signal Detection and Recognition using computer vision and roadside camera

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Outline

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- ❑ Literature Review
- ❑ Methodology
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Introduction

Vehicle-Based Traffic Signal Information

- Traffic Sign Recognition (TSR) system
- Autonomous Driving

Roadside-Based Traffic Signal Information

- Automatic ATSPM (Automated Traffic Signal Performance Measure)
- CV2X SPaT (Signal Phase and Timing)

Introduction

Background

- Traffic Signal Information is a crucial part for ITS and autonomous vehicles.
- Autonomous vehicle can perceive traffic signals using on-board camera sensor.
- Traffic signal data can be transmitted through CV2X communication (SPaT). However, that relies on infrastructure upgrade/maintenance/operation

Motivations:

- Advances in computer vision provides efficient tools for detecting traffic signals using roadside camera
- Support ATSPM and CV2X SPaT without significant infrastructure upgrade.

Research Objectives:

- Develop and implement methodologies for traffic signal recognitions using roadside CCTV camera
- Compare multiple state-of-the-art computer vision methodologies in traffic signal recognition

Literature Review

Vehicle-Based Traffic Signal Recognition

- Traditional image processing

  Hough Transform, edge detection, etc (Omachi and Omachi, 2009)

  Color segmentation (Diaz-Cabrera et al., 2015, Wang et al., 2011)

- Two-step pipeline

  Object detection (Faster-CNN, YOLO)

  Color Recognition (PCA, SVM, color-threshold, YOLO classifier)

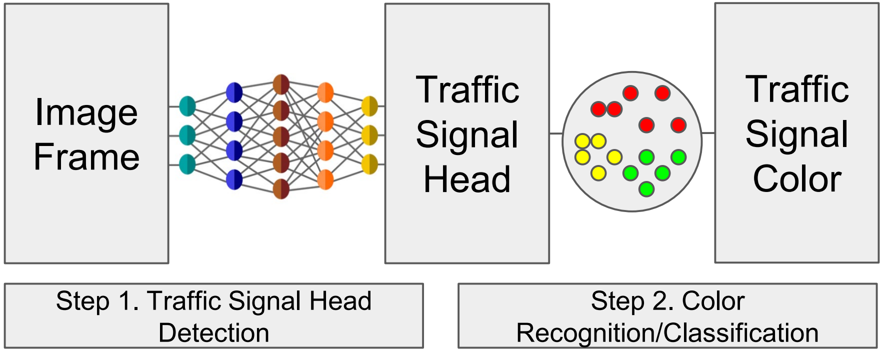
- End-to-end detection

  Deep-learning based (Saker and Meng, 2022)

Literature Review

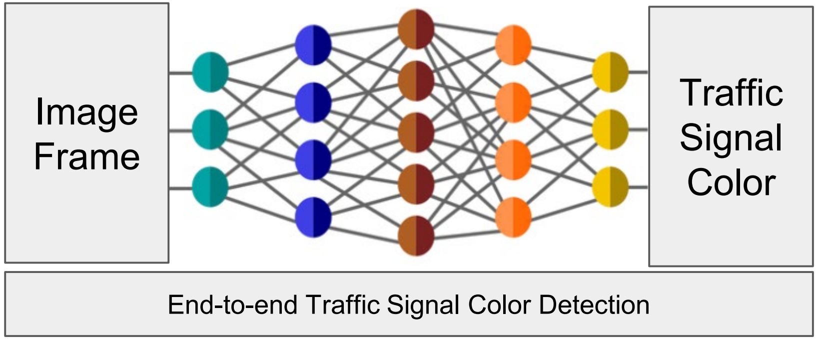
Two-step pipeline

- Two separate models
- More modular, but more complex
- Needs coordination between stages
- Slower process speed
- Can separately diagnose detection and classification, easier to debug



End-to-end detection

- Single model for detection and classification
- Simpler pipeline
- Straightforward
- Faster process speed
- Hard to isolate detection vs, classification errors, harder to debug



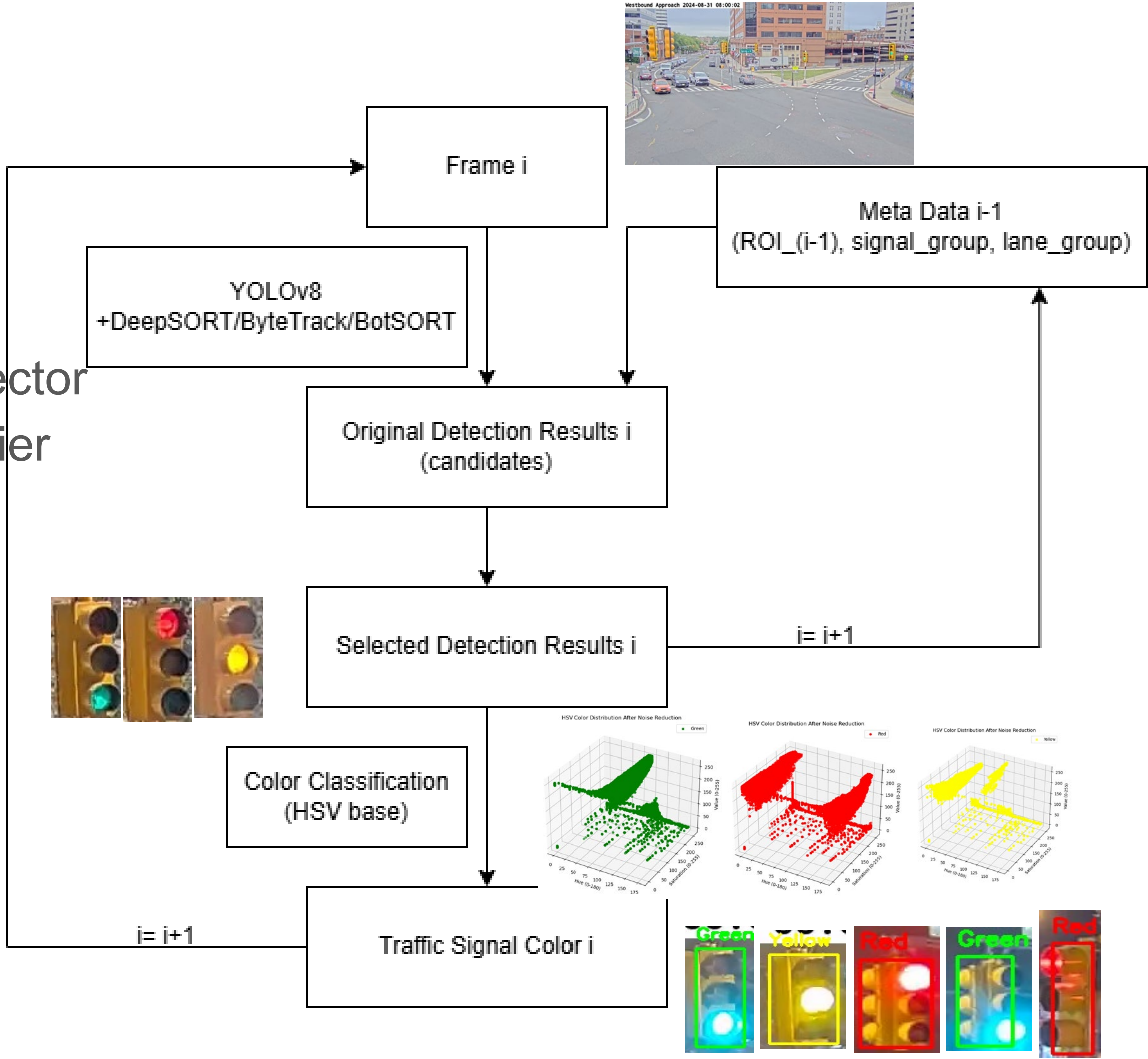
Methodology

In this study, we adopt a:

- Two-step recognition method
- Object detection: YOLOv8 detector
- Color Recognition: HSV classifier

We also employ:

- Pre-defined metadata



Methodology

We also adopt a:

- Two-step recognition method
- Object detection: YOLOv8 detector
- Color Recognition: YOLOv8 classifier

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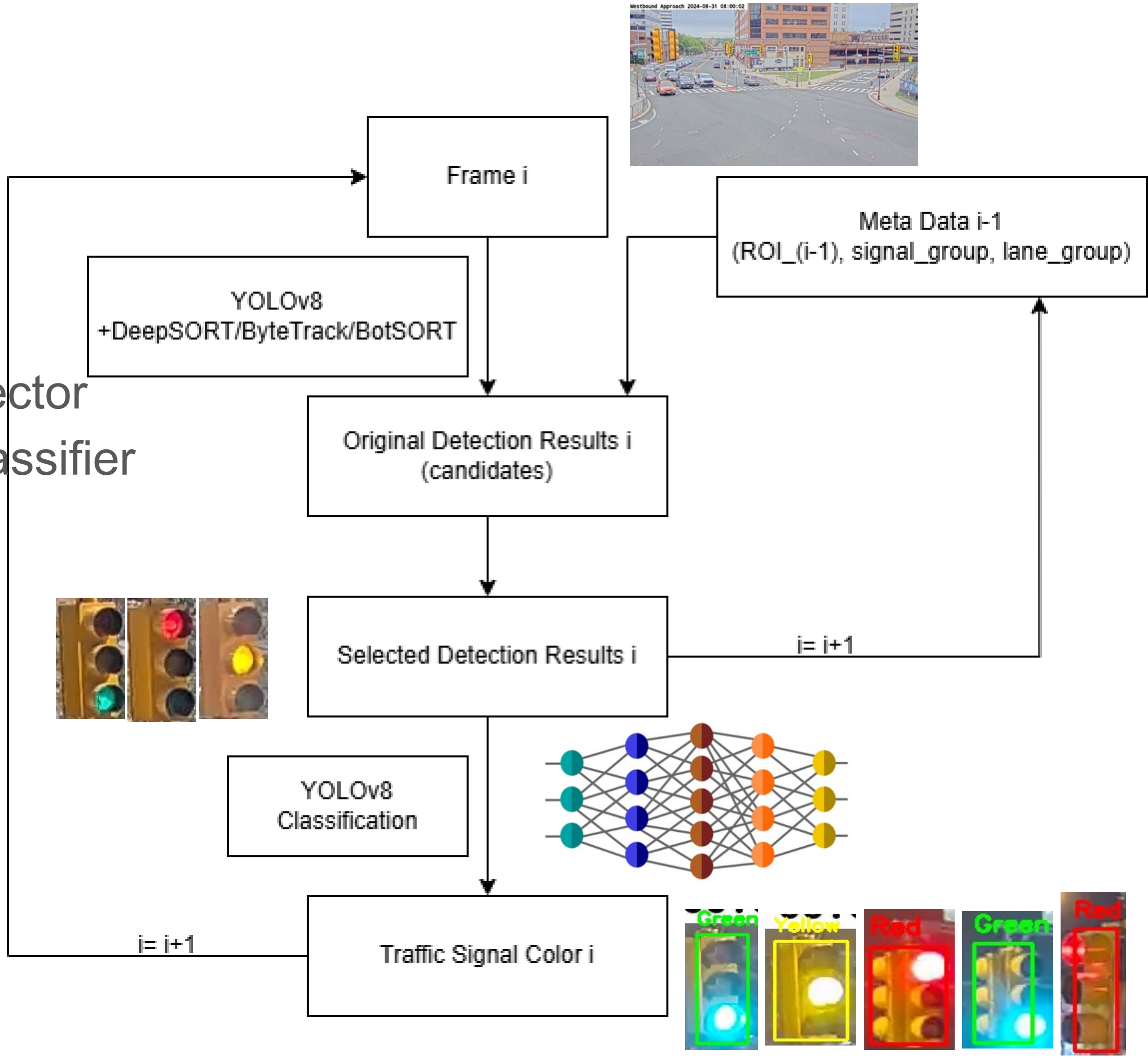


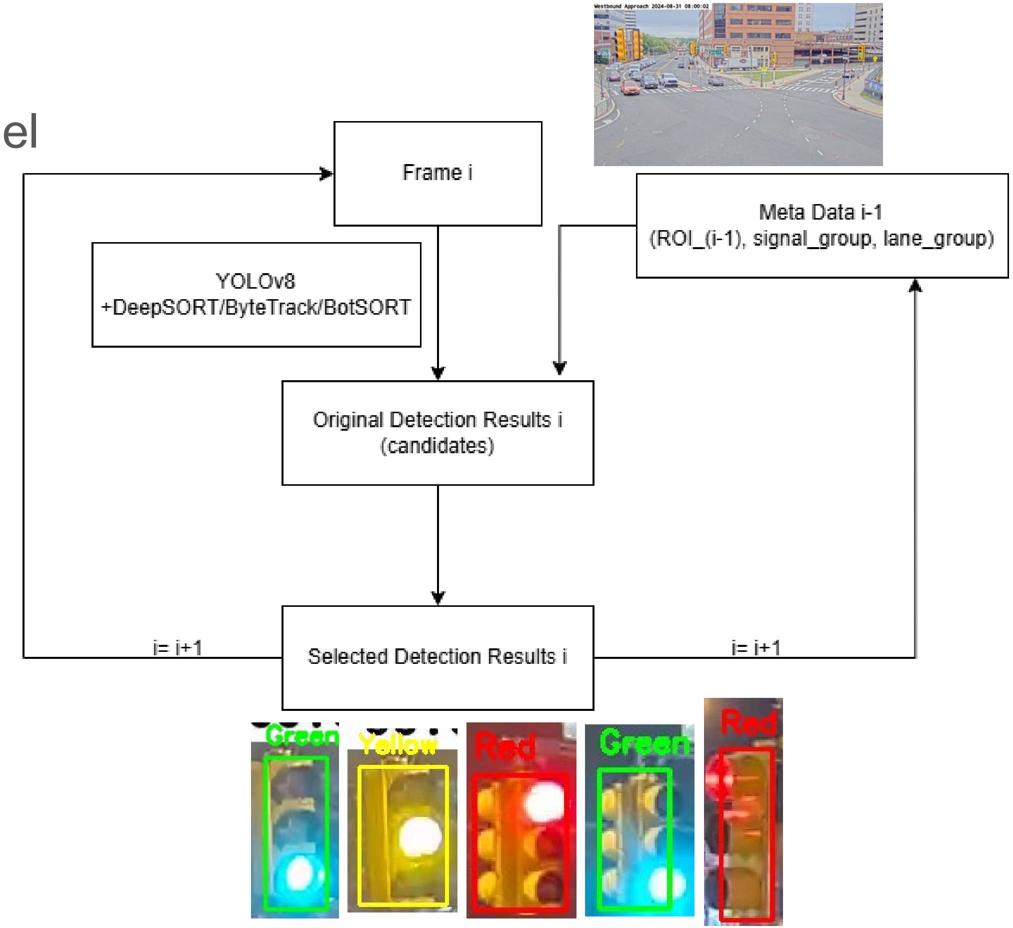
Methodology

Additionally, we train an end-to-end model

- YOLOv8 object detection

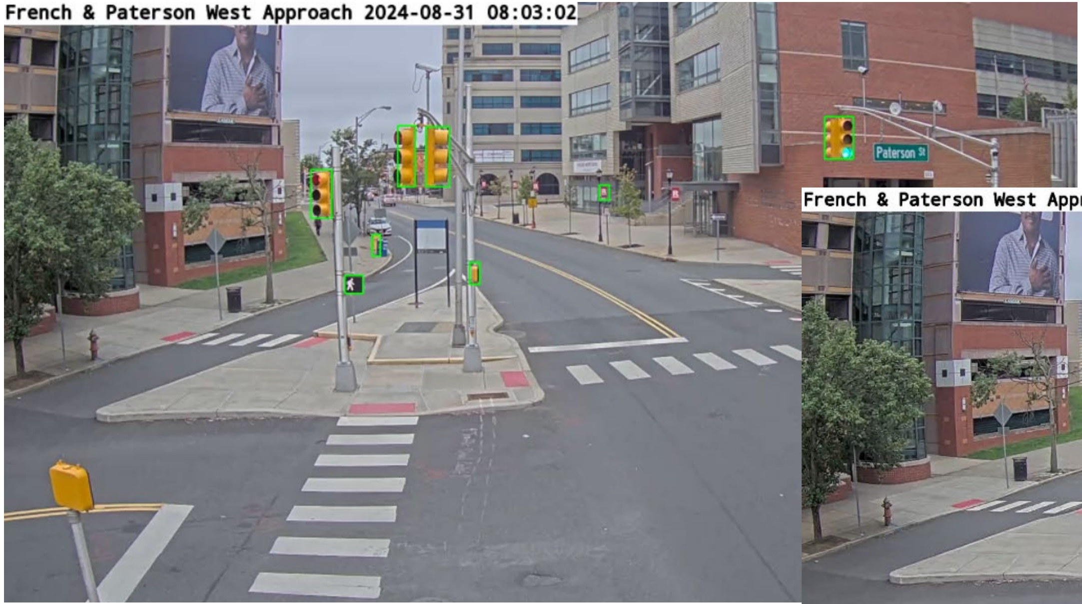
We also employ:

- Pre-defined metadata



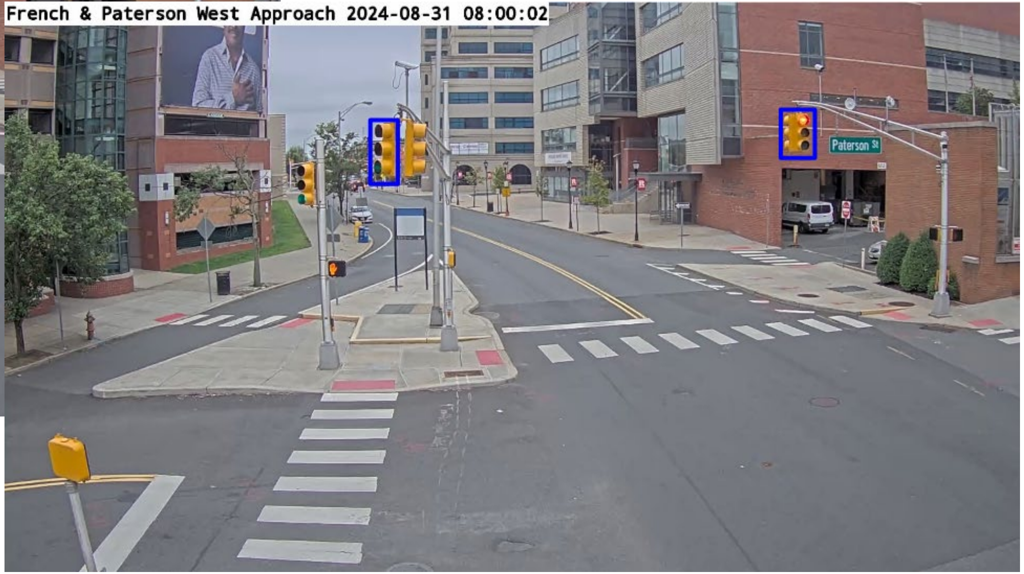
Methodology

The pre-defined metadata ROIs (Region of Interest) increase the detection reliability



Left: Raw YOLOv8 detection results

Right: true signal head ROI



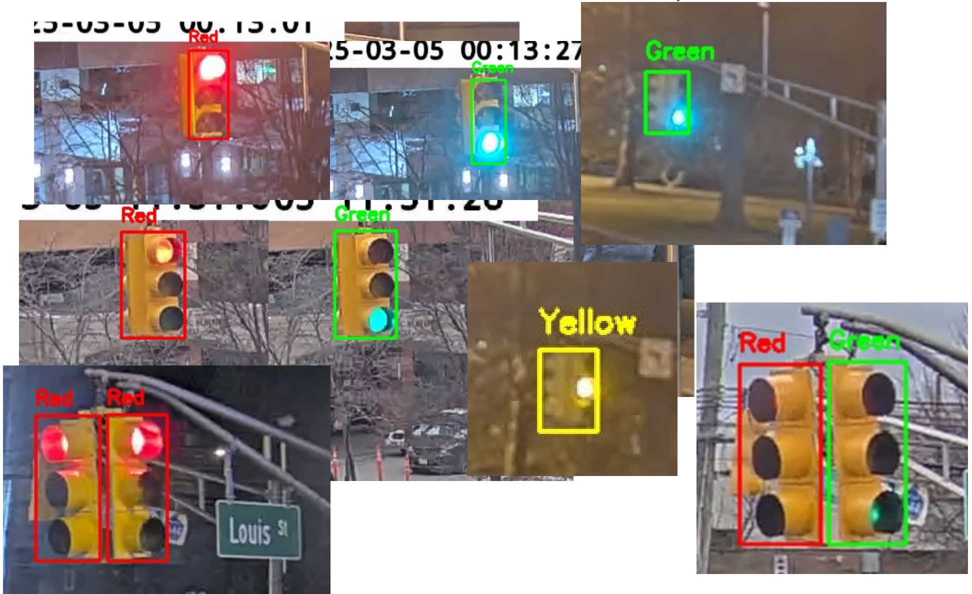
Data Description

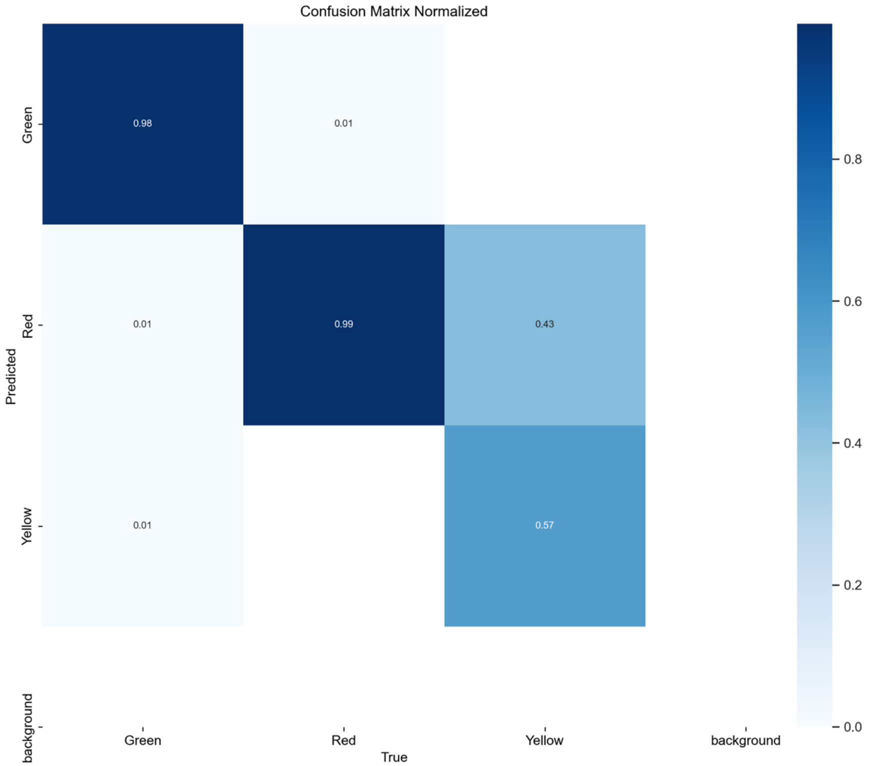
- This study utilizes video data from DataCity Smart Mobility Testing Ground
- 24 hours of video data
- Five signalized intersections
- Route 27 in New Brunswick, New Jersey.

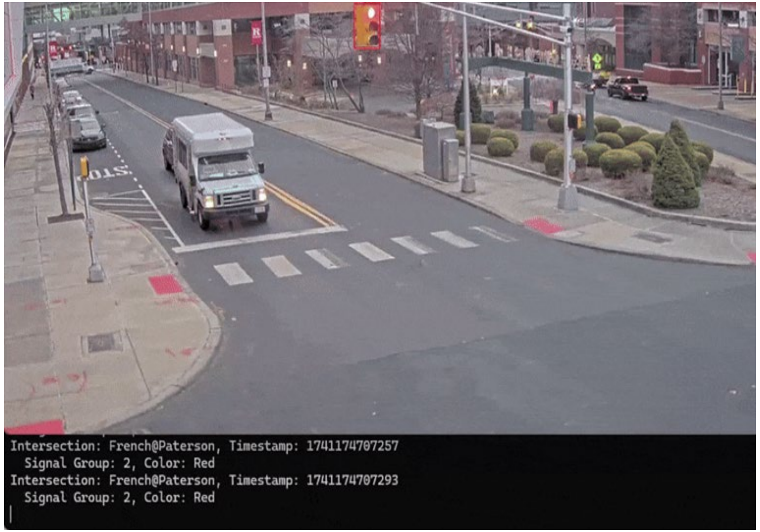
Intersection Name	Signal Control Type	Phase Number	Cycle Length (s)
Albany & George	Responsive	2	80
Albany & Easton	Fully Actuated	4	47-120
French & Joyce Kilmer	Fully Actuated	3	35 - 101
French & Paterson	Pre-timed	2	70
French & Suydam/Louis	Semi-Actuated	2	76-110

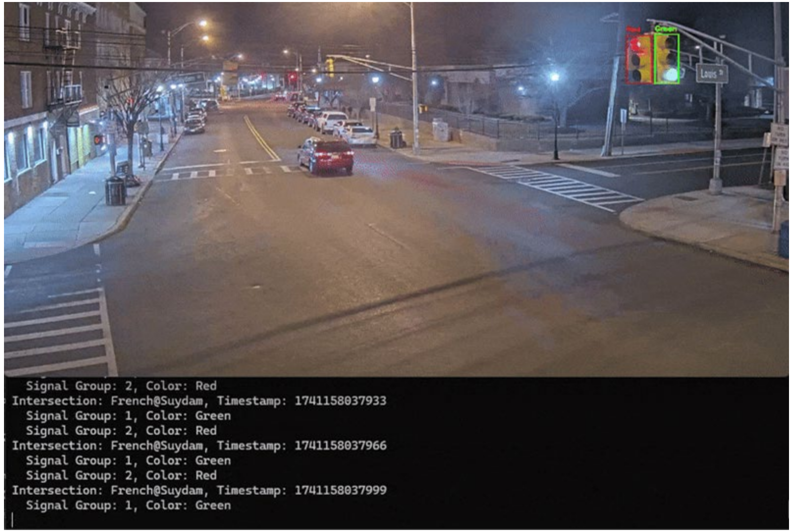
Model Evaluation

- Overall accuracy: 84.7%
- Per-Class accuracy:
  - Green: Precision: 98%, Recall: 98%
  - Red: Precision: 69%, Recall: 99%
  - Yellow: Precision: 98%, Recall: 57%

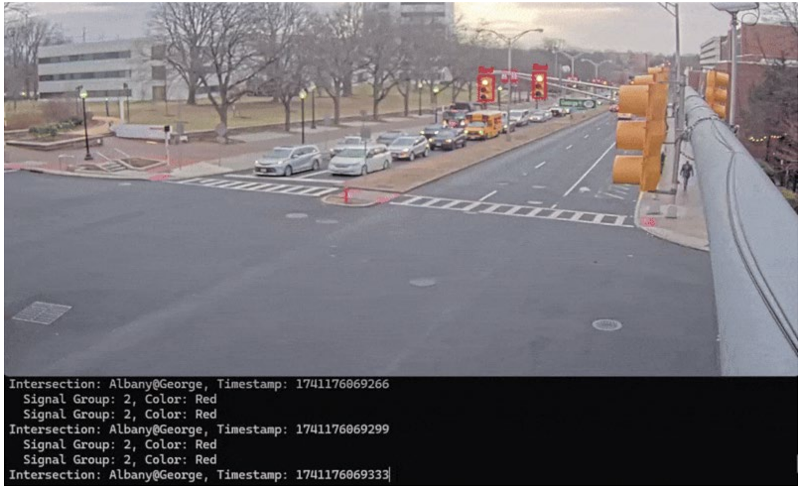





Intersection: French@Paterson, Timestamp: 1741174707257
Signal Group: 2, Color: Red
Intersection: French@Paterson, Timestamp: 1741174707293
Signal Group: 2, Color: Red


Green
Signal Group: 2, Color: Red
Intersection: French@Suydam, Timestamp: 1741158037933
Signal Group: 1, Color: Green
Signal Group: 2, Color: Red
Intersection: French@Suydam, Timestamp: 1741158037966
Signal Group: 1, Color: Green
Signal Group: 2, Color: Red
Intersection: French@Suydam, Timestamp: 1741158037999
Signal Group: 1, Color: Green


EMPLOYEE
Intersection: French@Joyce, Timestamp: 1741174214633
Signal Group: 2, Color: Green
Signal Group: 1, Color: Green
Intersection: French@Joyce, Timestamp: 1741174214666
Signal Group: 2, Color: Green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Intersection: Albany@George, Timestamp: 1741176069299
Signal Group: 2, Color: Red
Signal Group: 2, Color: Red
Intersection: Albany@George, Timestamp: 1741176069333

Conclusions

- This study compared multiple cutting-edge detection methods for traffic signal detection and recognition
- The proposed method takes advantage of roadside camera to further enhance the object detection reliability
- The proposed method reaches an overall accuracy of 84.7%
- The proposed method supports real-time traffic signal data logging and transmission for potential ATSPM and CV2X applications

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Thank You

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