Air Sensor International Conference 2022

Session 2C: Sensor Networks: From nuts and bolts to real-world impacts

Title: Air pollution monitoring in Vietnam with low-cost sensor network

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Introduction

- Motivation:
  - Air pollution is a rising concern in developing countries, such as Vietnam.
  - Using dust sensor for air quality inspection would be expensive.
- In this work:
  - We develop our low-cost sensor using commercial PMS7003 sensor.
  - We explore the possibility of using vehicle tracking system as an alternative to estimate dust concentration.
  - We implement different vehicle detection methods based on background subtraction combined with classifier method and YOLOv5 along with Kalman Filter and Hungarian algorithms for tracking purpose.

Related Works

- V. T. Tang et al showed when there was a slow traffic flow velocity during rush hours, there were usually higher levels of air pollutants [1].
- Giang and Kim Oanh also showed in their work that roadside air pollution concentrations were extremely high when the traffic flows peaked [2].

⇒There might be a relationship between traffic density and PM25 concentration.

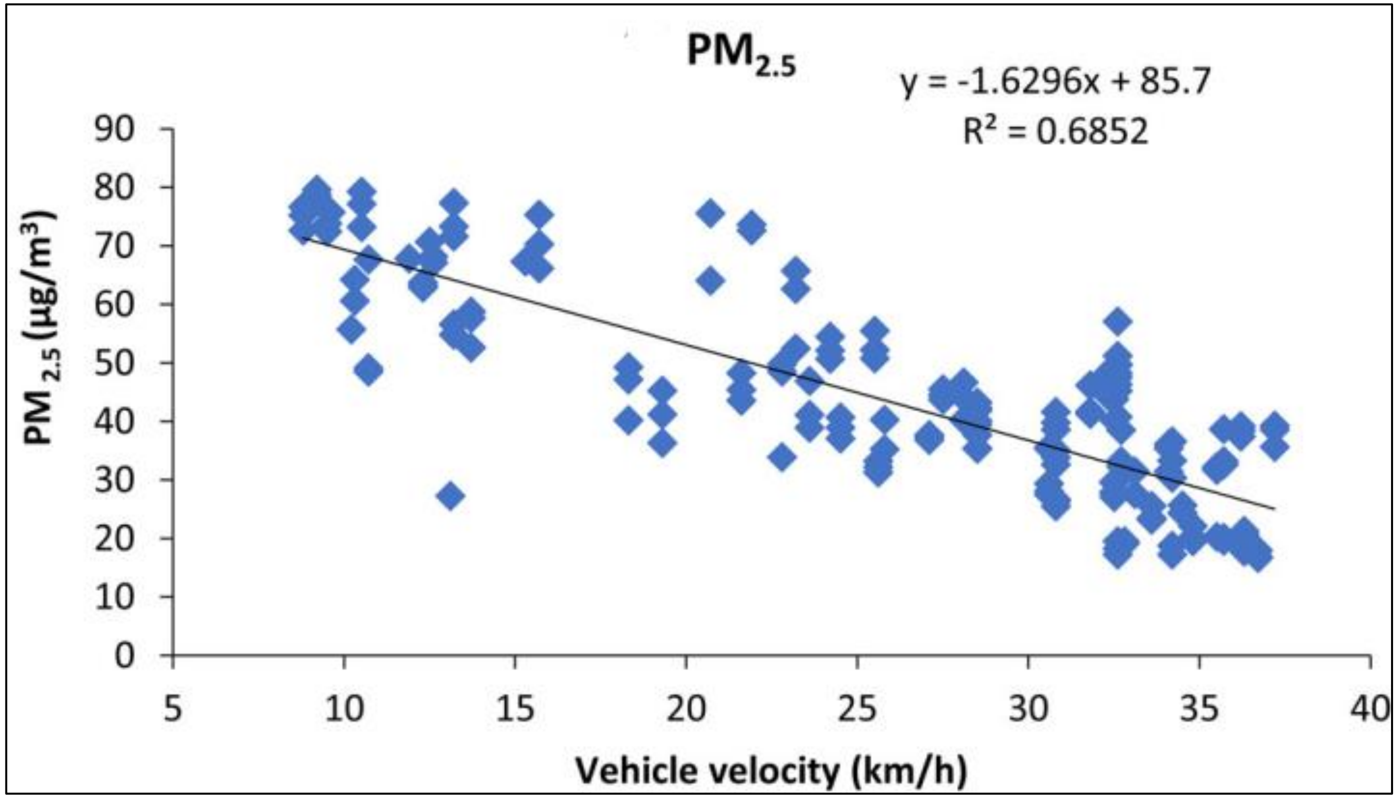


Figure1: Relationship between the hourly traffic flow velocity and PM25 concentration. [1]

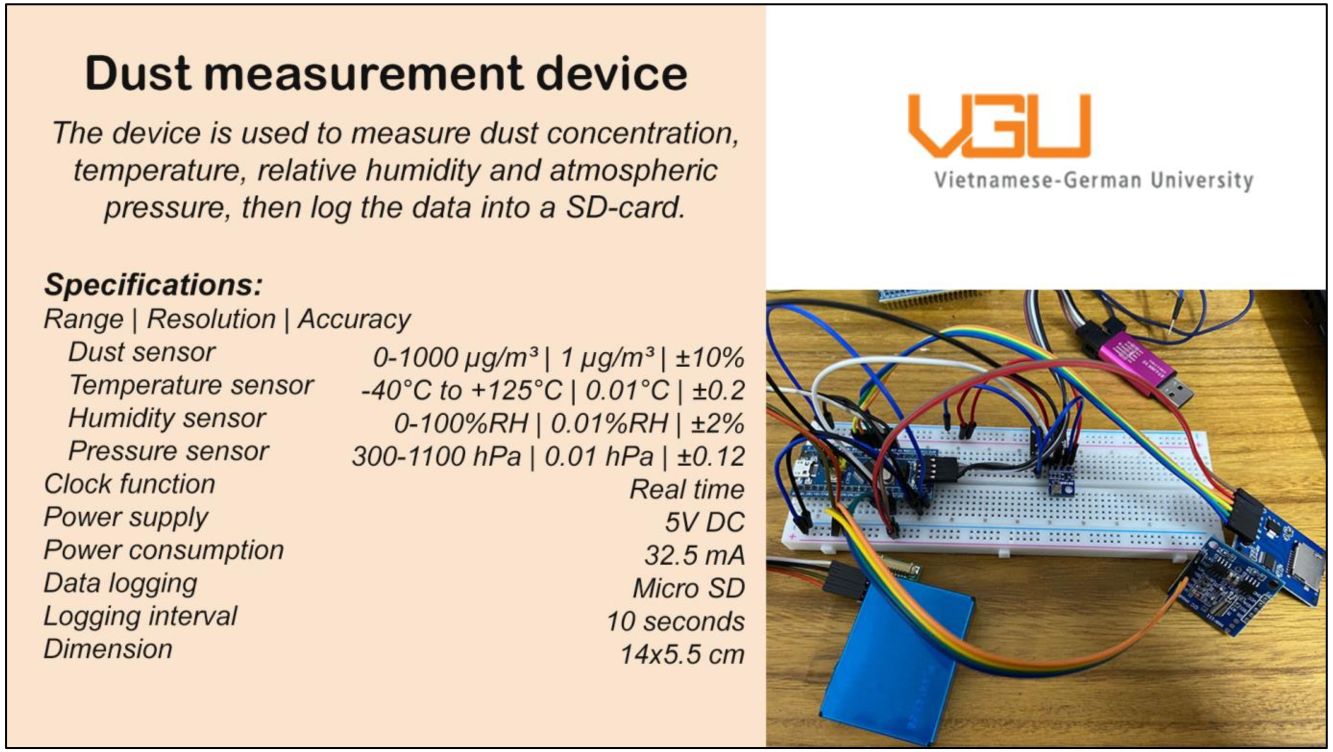
Related Works

- Object detection models are being used for vehicle tracking in air pollution monitoring [3].
- Faster-RCNN [4] and YOLO [5] have been used for object recognition object detection tasks in vehicle surveillance problem.
- In [3], YOLOv5 and Faster-RCNN were used as detectors of the air pollution estimation system, and YOLOv5 showed a more reliable results.

Methods

Dust Measurement Device

- We develop a dust measurement device based on the PMS7003 sensor.
- The measuring principle is based on light scattering technique.
- Light scattering technique:
    - Light beam is passed through an air sample.
    - The scattered light is used to measure and calculate the particle concentration.
- The module also measures temperature, humidity, and sensor.




PMS7003

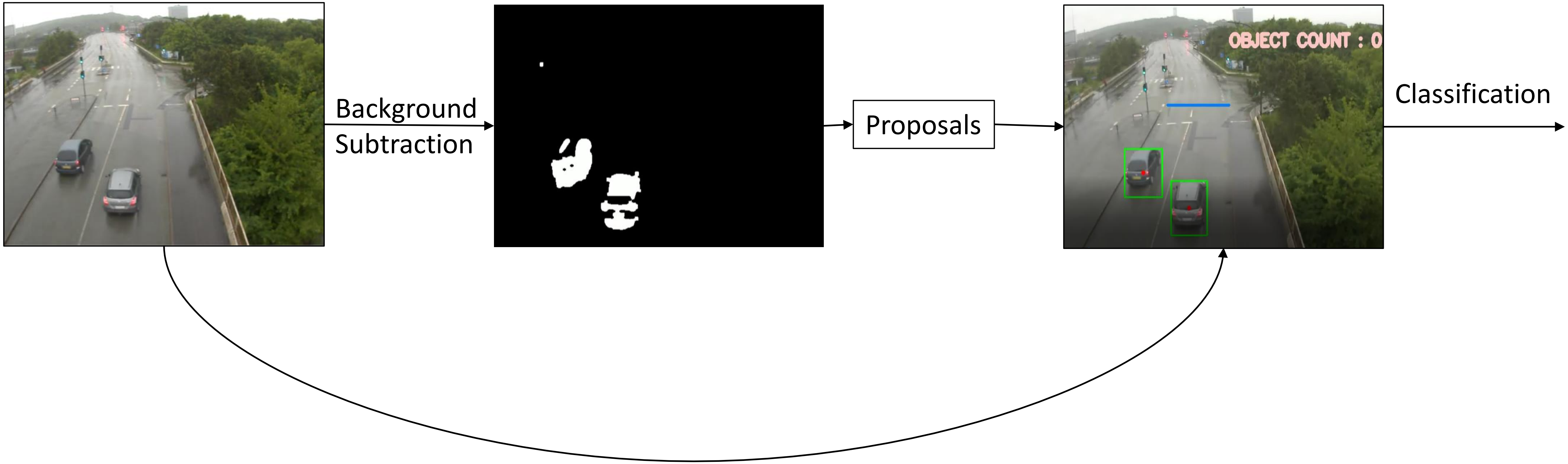
Vehicle Tracking System

- 1. Detector: an algorithm to detect objects of interest.
  - Background subtraction.
  - Object detection models (YOLOv5 [5]).
- 2. Prediction and Update: Kalman Filter[6].
  - with constant acceleration assumption.
- 3. ID assignment: match prediction result with the detection result (Hungarian Algorithm[7]).

Vehicle Detector: Background Subtraction and YOLOv5

- Background subtraction:
  - Get moving object by eliminate the background.
  - Cluster the white pixels and draw bounding box.
- YOLOv5 object detection model pretrained with COCO dataset [5, 10].

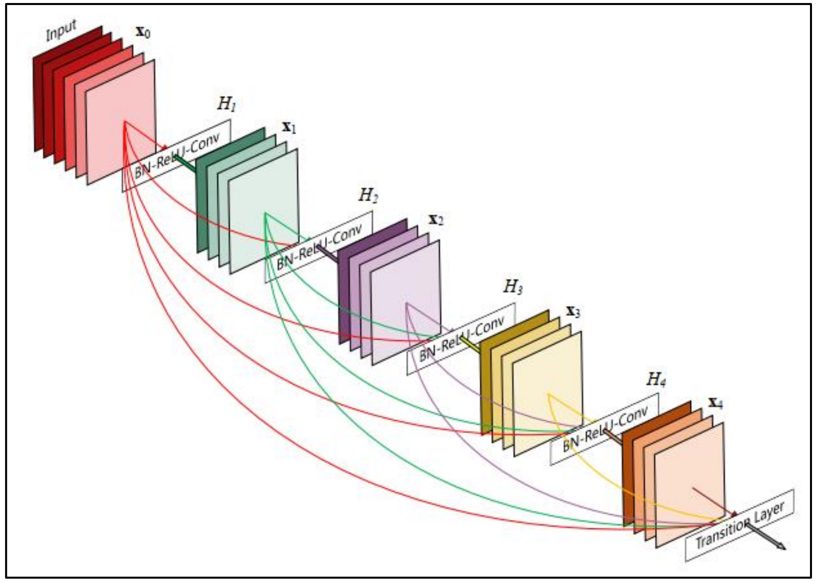
Background Subtraction + Classification

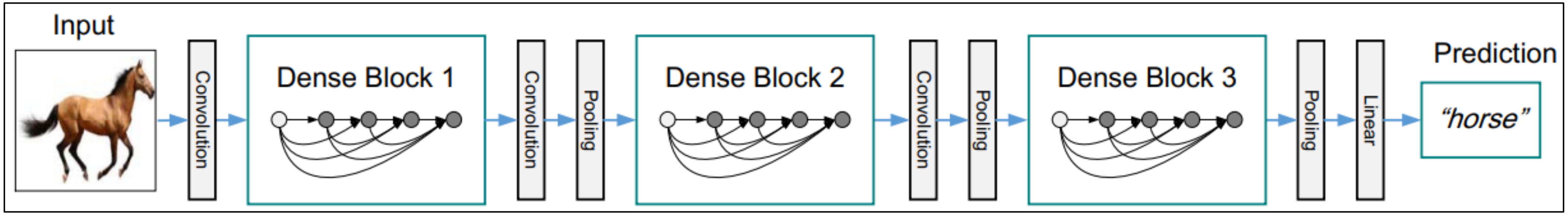


DenseNet Classifier for Classifcation

- DenseNet [9] pretrained with ImageNet is finetuned from data collected on the field.
- From the vehicle tracking system based on background subtraction, its outputs are fed to the DenseNet classifier.
- The classification outputs are class of the object (car and motorbike) and their confidence score.

5-layer Dense block [9]





A deep DenseNet architecture [9]

Experiments & Results

Vehicle Tracking System with Background Subtraction Evaluation

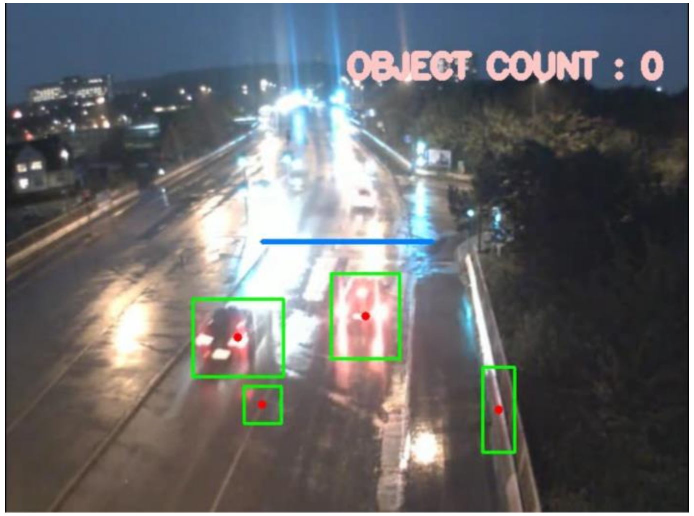
- Background Subtraction with Kalman Filter system is evaluated on a part of AAU dataset.
- The AAU data contains five-minute videos of different street intersections of Aalborg and Viborg cities in Danish with varied illuminations and weather conditions [8].
- AAU RainSnow Traffic Surveillance is first presented by C. H. Bahnsen and T. B. Moeslund in their work [8].

AAU Mild Rain

AAU Heavy Rain

AAU Strom Condition

AAU Light Disturbance



Performance Evaluation of Background Subtraction based Vehicle Tracking

AAU Strom Condition	Recall	Precision	AAU Heavy Rain	Recall	Precision
Background Subtraction	0.60	1.00	Background Subtraction	0.42	0.89
Kalman Filter with constant acceleration constraint	0.90	0.93	Kalman Filter with constant acceleration constraint	0.76	0.69

AAU Mild Rain	Recall	Precision	AAU Light Disturbance	Recall	Precision
Background Subtraction	0.88	0.94	Background Subtraction	0.71	0.33
Kalman Filter with constant acceleration constraint	1.00	0.85	Kalman Filter with constant acceleration constraint	0.93	0.49

Vehicle Tracking System: Background Subtraction Detector

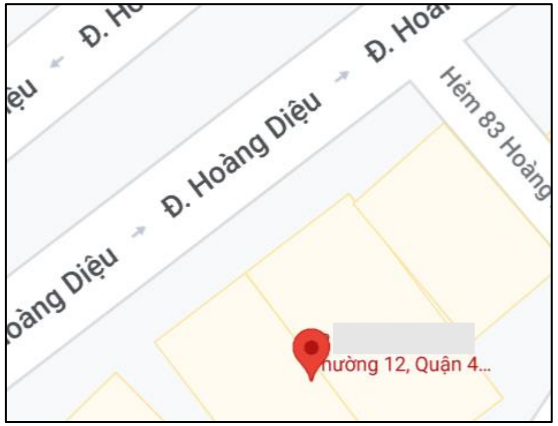
Without Kalman Filter and Hungarian algorithm

With Kalman Filter and Hungarian algorithm

Experiment: Sensor Node Placement

- Conducted in Ho Chi Minh city in the south side of Vietnam.
- 2 sensor node locations:
  - District 4, Ho Chi Minh city. (from July 1, 2021, to July 6, 2021) (record 10 minutes for every hour).
  - Thu Duc District, Ho Chi Minh city. (April 15, 2022, and April 18, 2022) (record continuously the whole days).

District 4



Thu Duc District

Ho Chi Minh city

Sensor Node Setup

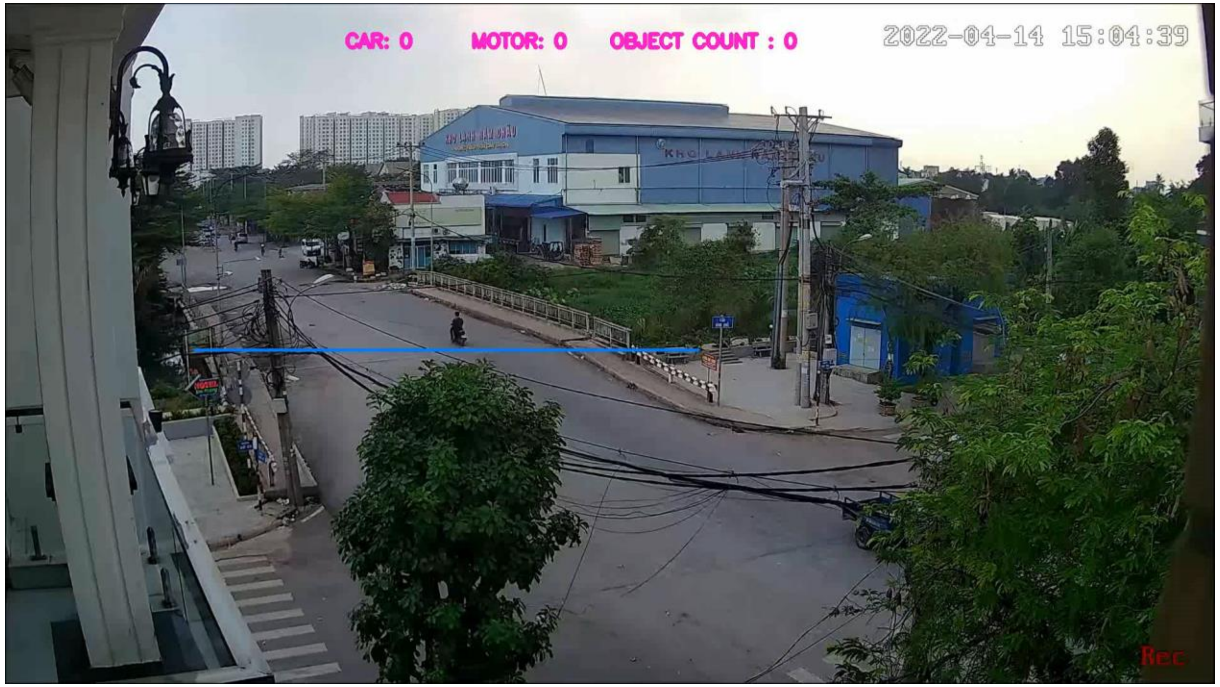
- 2 Pairs of a dust measuring module and vehicle tracking system were set up in District 4 and Thu Duc District in Ho Chi Minh city.
- Camera in District 4:
  - Model: KBONE KN-4001WN
  - Resolution: 4MP
- Camera in Thu Duc District:
  - Model: V380
  - Resolution: 5MP

Vehicle Tracking system

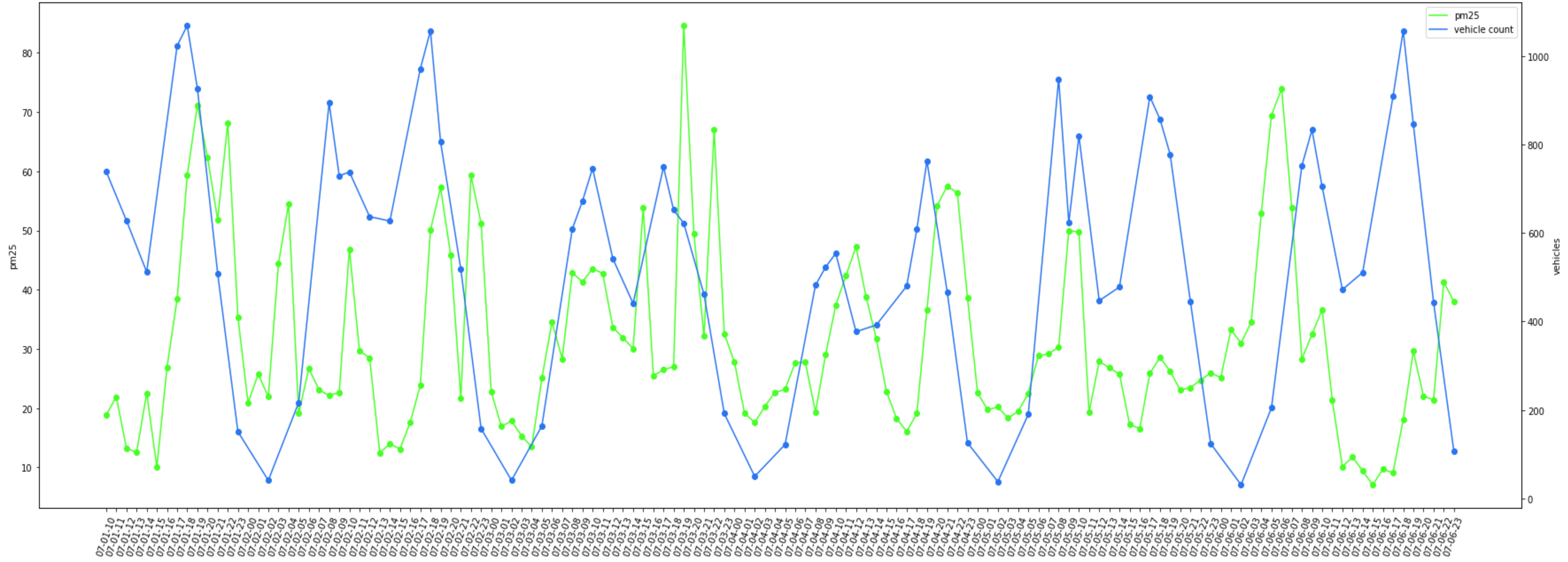
- Demo Result from video collected in District 4 and Thu Duc District in Ho Chi Minh city.

District 4

Thu Duc District

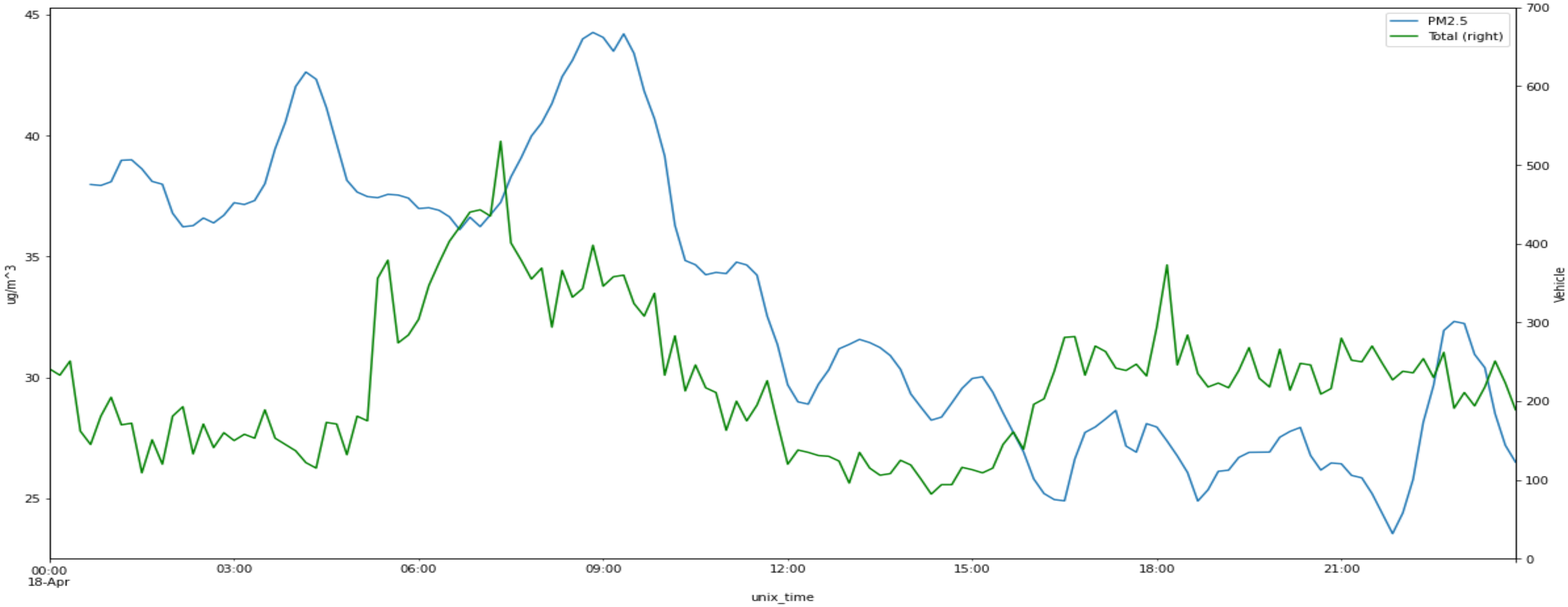


Number of vehicles influences the PM2.5 concentration in District 2 area
(Using Background Subtraction based Vehicle Tracking System)
(from July 1, 2021, to July 6, 2021).



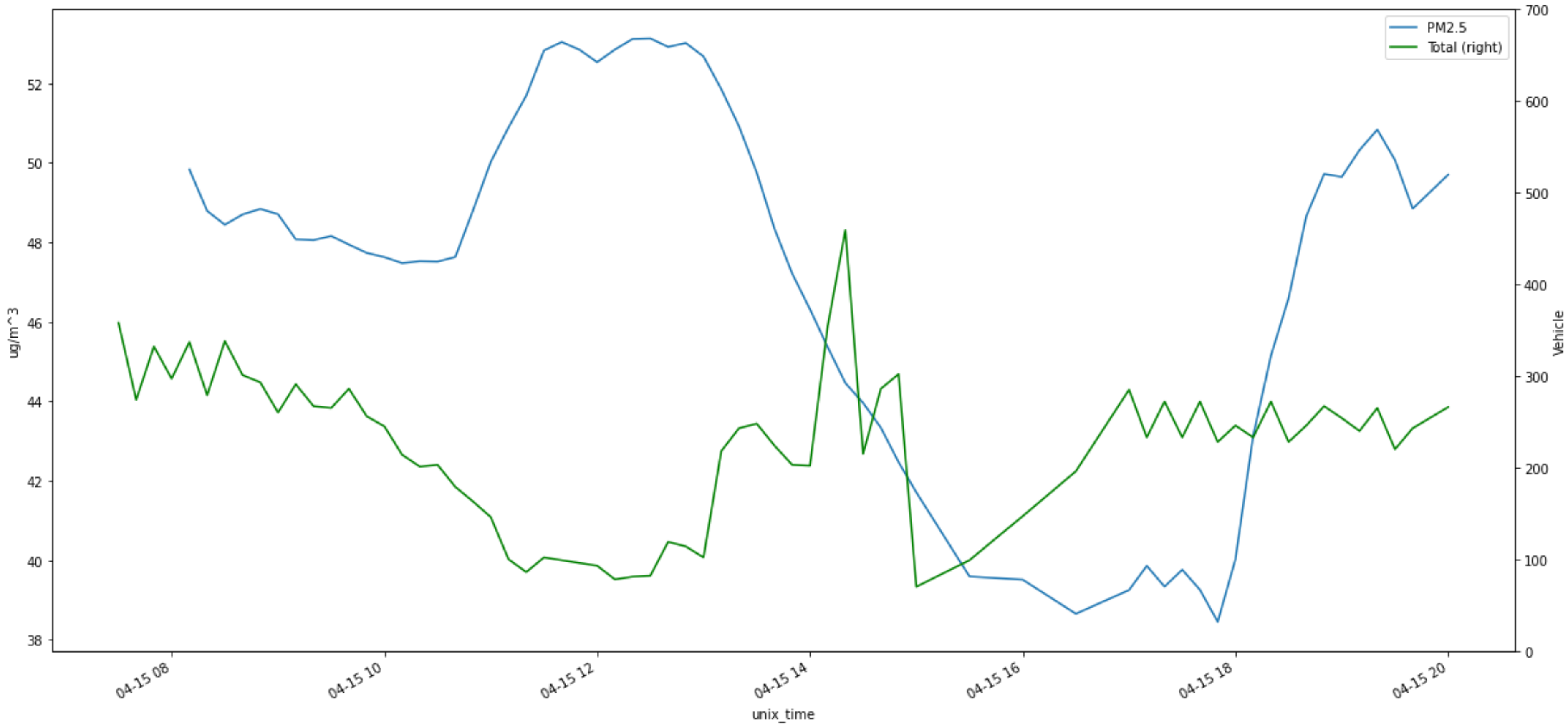
- The PM2.5 tended to increase when there were more vehicles crossing and decrease when there were less vehicle.
- The changing pattern was not obvious, and there were delays in each changes.
- The correlation between PM2.5 concentration and traffic density was clear.

Number of vehicles influences the PM2.5 concentration in Thu Duc District area (Using Background Subtraction based Vehicle Tracking System) (on July 18, 2022).



- The PM25 still tended to increase when there were more vehicles crossing and decrease when there were less vehicle.
- The changing amount had no pattern, and delays were observed in each changes.
- The correlation between PM2.5 concentration and traffic density was not as clear as in sampled record experiment.

Number of vehicles influences the PM2.5 concentration in Thu Duc District area (Using Background Subtraction based Vehicle Tracking System) (on July 15, 2022).



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- The changing pattern was not obvious, and there were delays in each changes.
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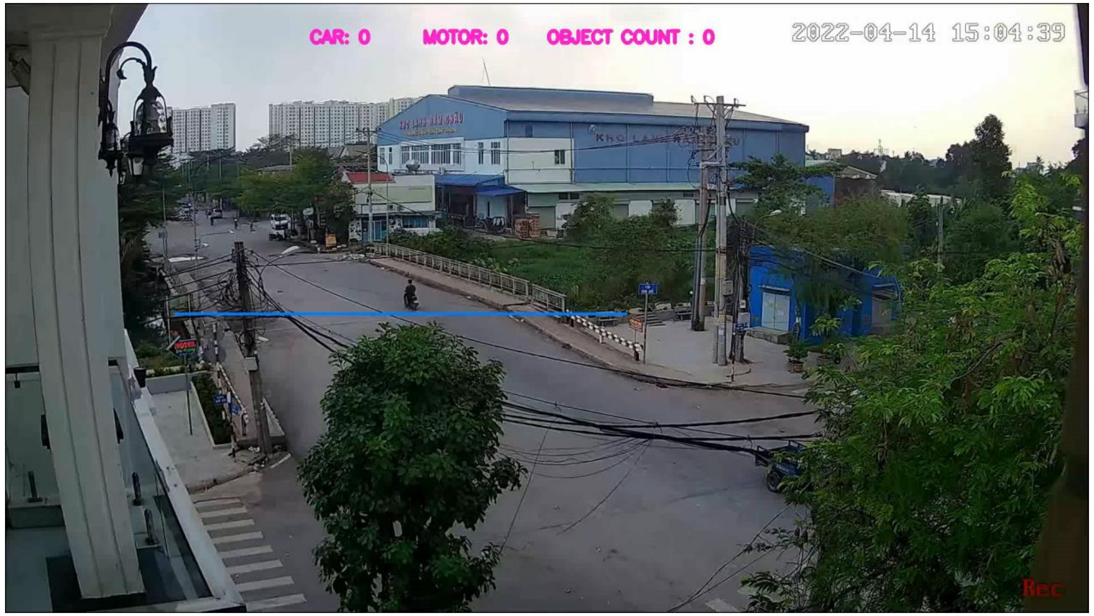
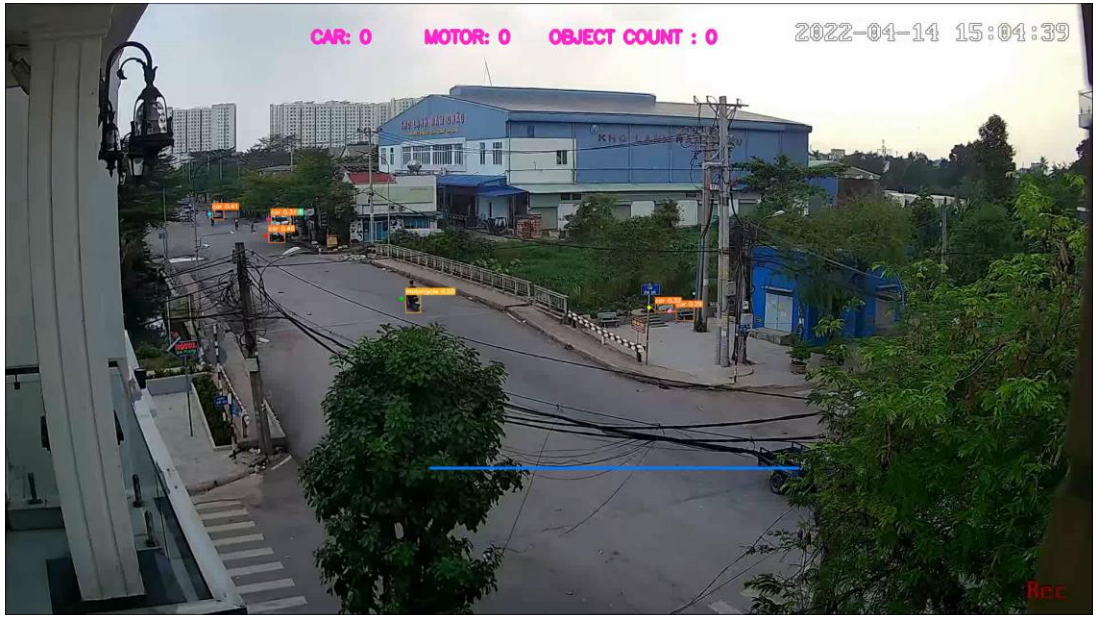
Background Subtraction + DenseNet and YOLOv5 Demos

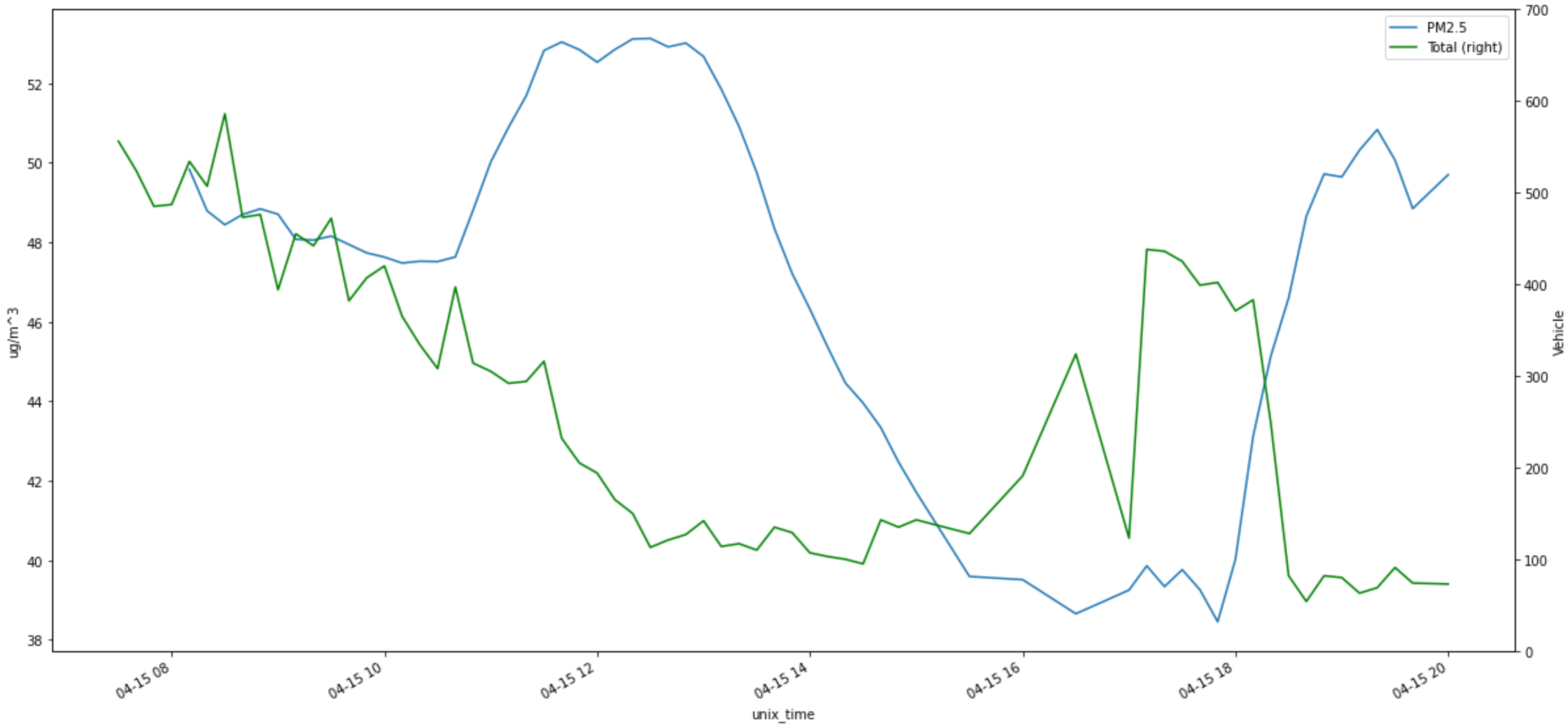
Background Subtraction + DenseNet



YOLOv5



Number of vehicles influences the PM2.5 concentration in Thu Duc District area (Using YOLOv5 based Vehicle Tracking System) (on July 15, 2022).



- The PM25 still tended to increase when there were more vehicles crossing and decrease when there were less vehicle.
- The changing amount had no pattern, and delays were observed in each changes.
- The correlation between PM2.5 concentration and traffic density was not as clear as in sampled record experiment.
- YOLOv5 based method did not give the same result as background subtraction-based methods. Nevertheless, the observed change in traffic density from both methods is similar.

Conclusion

- A system for Air Quality Inspection with dust device measurement and vehicle tracking system is developed.
- A correlation between PM2.5 concentration and traffic density is usually observed.
- The correlation can be observed better from sampled video recorded in multiple days than videos continuously recorded in a day.
- We also proposed an algorithm for vehicle tracking purpose with the combination between background subtraction, DenseNet, Kalman Filter, and Hungarian methods.
- In future works, comparisons between multiple methods can be done regarding the performance of PM2.5 concentration prediction and estimation.
- Moreover, with classification of vehicle types, their effects on PM2.5 concentration can be further analyzed in further development.

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