Vision Zero Research on the Road, Part 5

AI-Based Video Analytics for Vehicle and Pedestrian Detection, Tracking, and Speed Estimation Using Traffic Cameras: Applications and Opportunities

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C2SMART University Transportation Center Led by New York University
Wednesday, November 16, 2022

Image source: n-ix

Agenda

- **Introduction - Video Analytics and AI for Smart Transportation**
- **Objectives**
- **What new stream of safety and mobility data can be generated from cameras**
- **How can we use them**
  - **Performance monitoring & evaluation**
    - Spatial & Temporal trends in vehicle and pedestrian density
    - Speed estimation and speeding detection
    - Dashboard & Map applications (e.g., near-miss hotspots)
    - And more!
  - **Real-time alerts**
    - Vehicle-to-Vehicle, Infrastructure-to-Vehicle, Infrastructure-to-VRUs

The **U.S. DOT** is committed to safety and innovation and sees artificial intelligence (AI), including natural language processing, ***computer vision***, and machine learning-based predictive analytics, as a promising capability to help achieve these aims.

- *Enabling the safe integration of AI into the transportation system*
- *Adopting and deploying AI-based tools into internal operations, research, and citizen-facing services*

DEPARTMENT OF TRANSPORTATION UNITED STATES OF AMERICA

https://www.transportation.gov/AI

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Video Analytics and AI for Smart Transportation

Computer vision can turn existing infrastructure into smart sensors in a myriad of ways, and new applications are being continuously developed. Some of the most recent and impactful uses are:

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CCTVs

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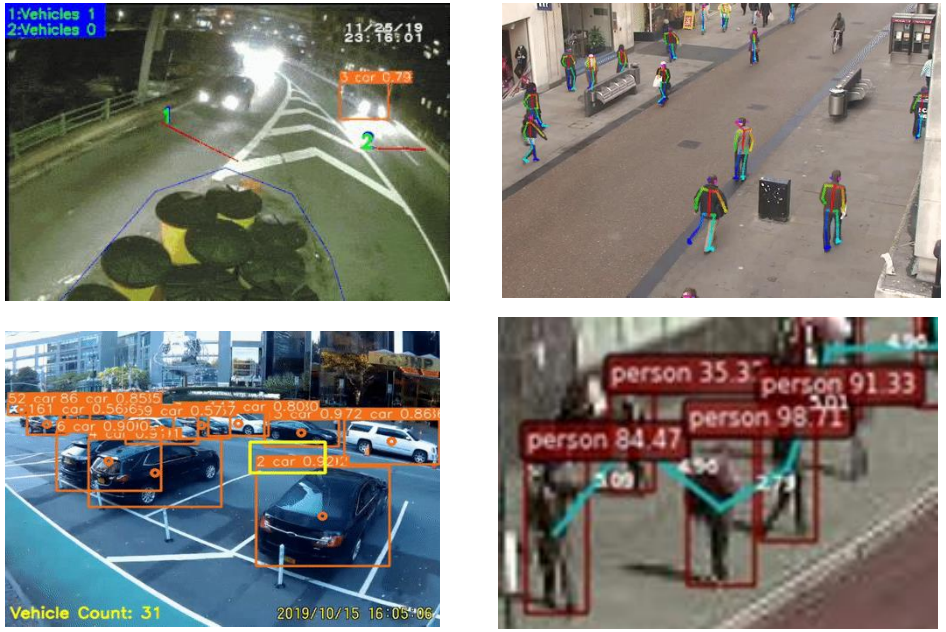
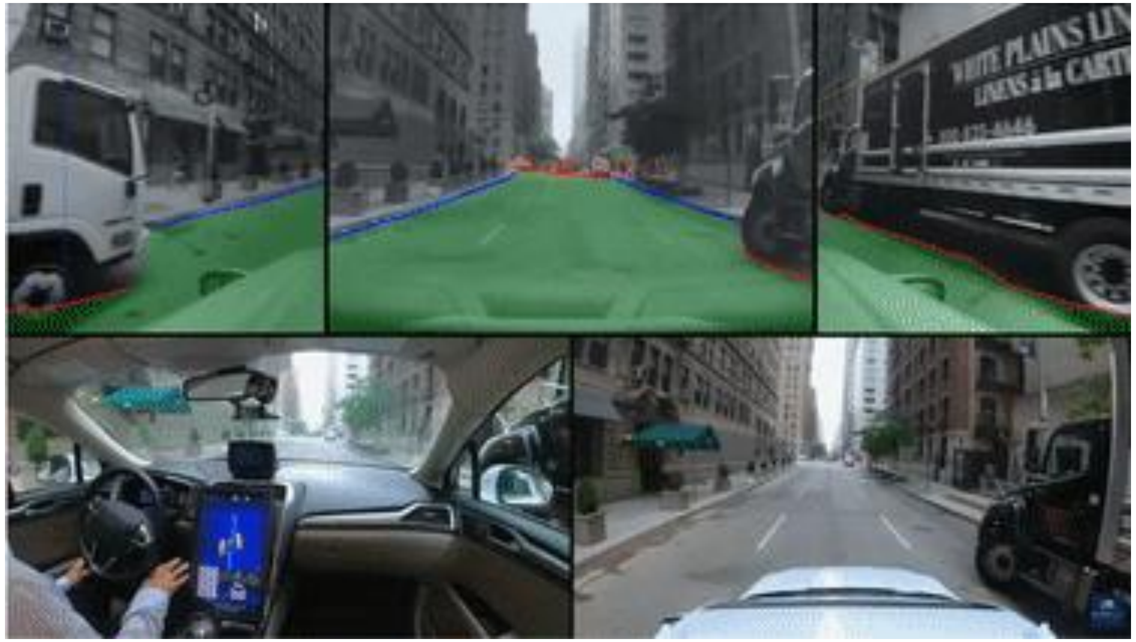
(a) Detect Parking Occupancy (b) Monitor Bus Lane Usage (c) Identify Double Parking



(e) Vehicle Tracking & Count (f) Pedestrian Detection & Social Distancing

Probe Vehicle/CAV-based Cameras

mobileye
An Intel Company



Sensing the driving scenes (Source: Mobileye)

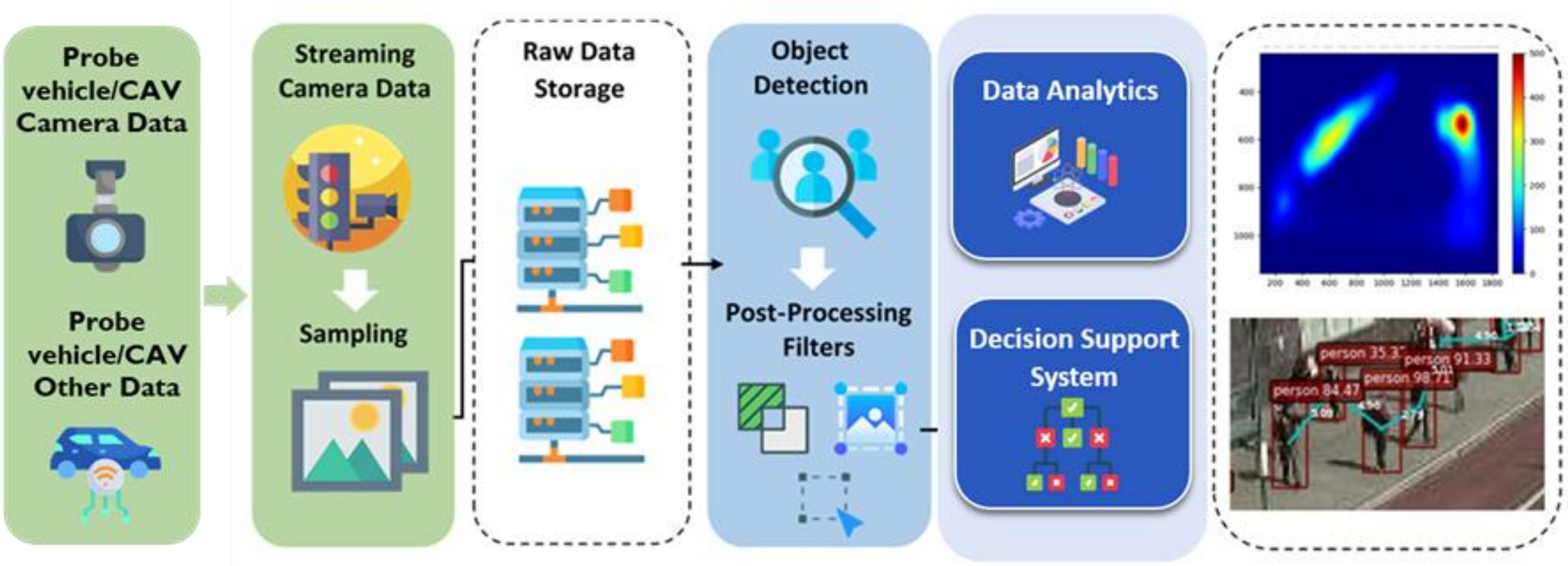
Current real-time roadway analysis through your windshield

Data-Driven Computer Vision Analytical Framework

NYU

How it works?

✓Leverages existing 900+ public CCTV traffic cameras
✓Real-time object detection for different classes
    ✓Pedestrians, Cars, Buses, Trucks and Cyclists
✓Post-processing filters and retrained model for NYC



Advantages:

1) Enables real-time detection

2) Builds on existing resources

3) Offers new performance & risk indicators for decision makers

4) Is easily adaptable to other cities or states.

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Zuo, F., Gao, J., Kurkcu, A., Yang, H., Ozbay, K., & Ma, Q. (2021) Reference-Free Video-to-Real Distance Approximation-Based Urban Social Distancing Analytics Amid COVID-19 Pandemic. Journal of Transport & Health.

Customized Training Data for NYC

- **The Microsoft COCO** (Common Objects in Context) dataset is a large-scale object detection, segmentation, and captioning dataset published by Microsoft. ~ 328K images, 91 objects (about 11 are traffic related)
- **CSMART Small scale image dataset for NYC** ~ 4,600 annotated using a customized annotation tool developed by C2SMART and images based on NYC CCTV traffic cameras

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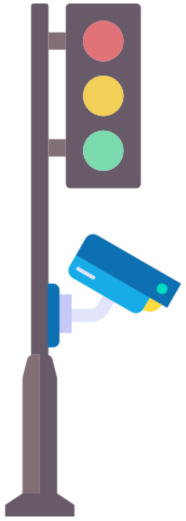
NYC DDC TOWN +GOWN

How Can We Use Them?

Performance Monitoring and Evaluation



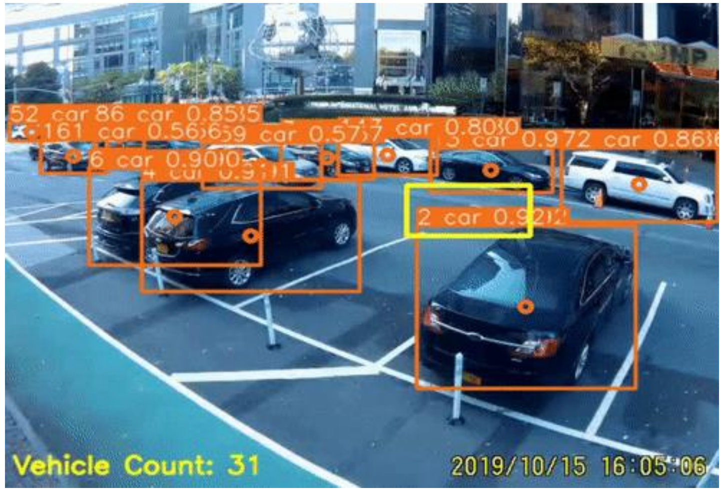

Real-time Alerts

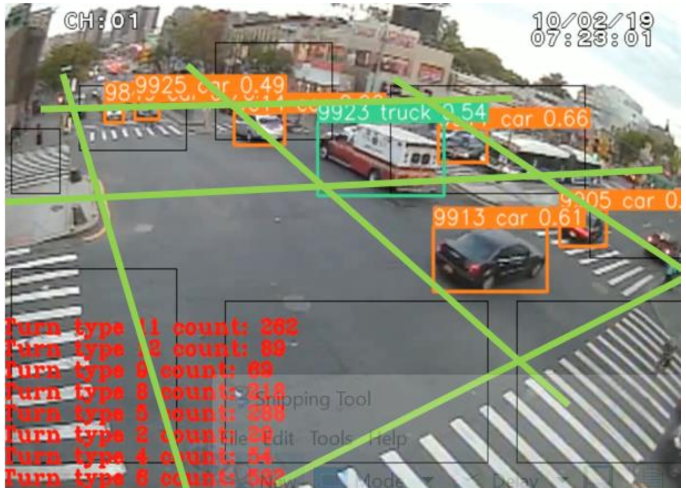


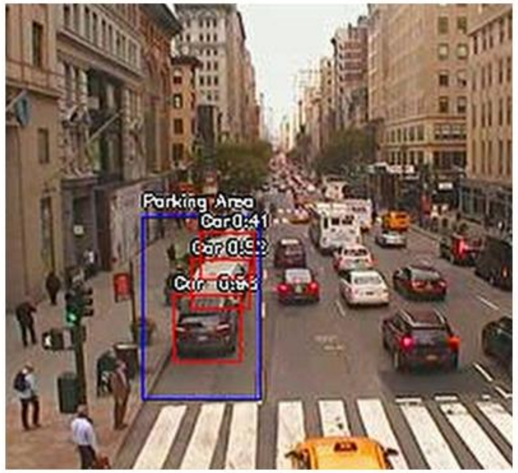

Performance Monitoring and Evaluation - Vehicles

Developed apps by C2SMART:

- Speed Estimation, Speeding detection
- Volume count; Turning movement count
- Queue detection/warning
- Curb lane management
- Accident/Illegal parking
- Vehicle-VRU near misses



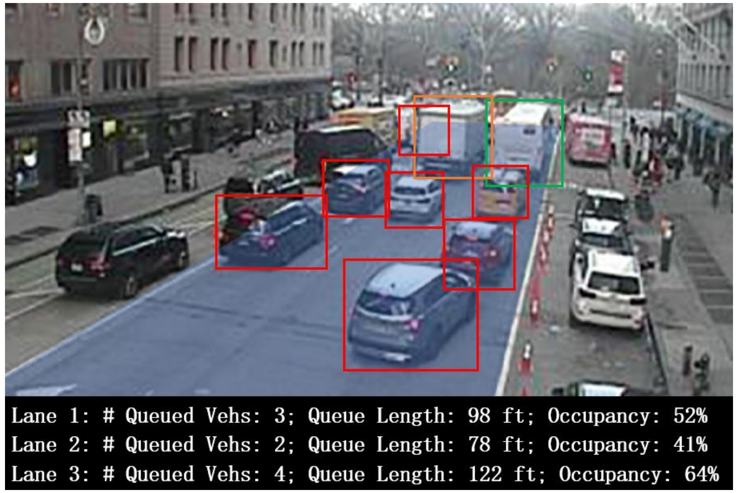


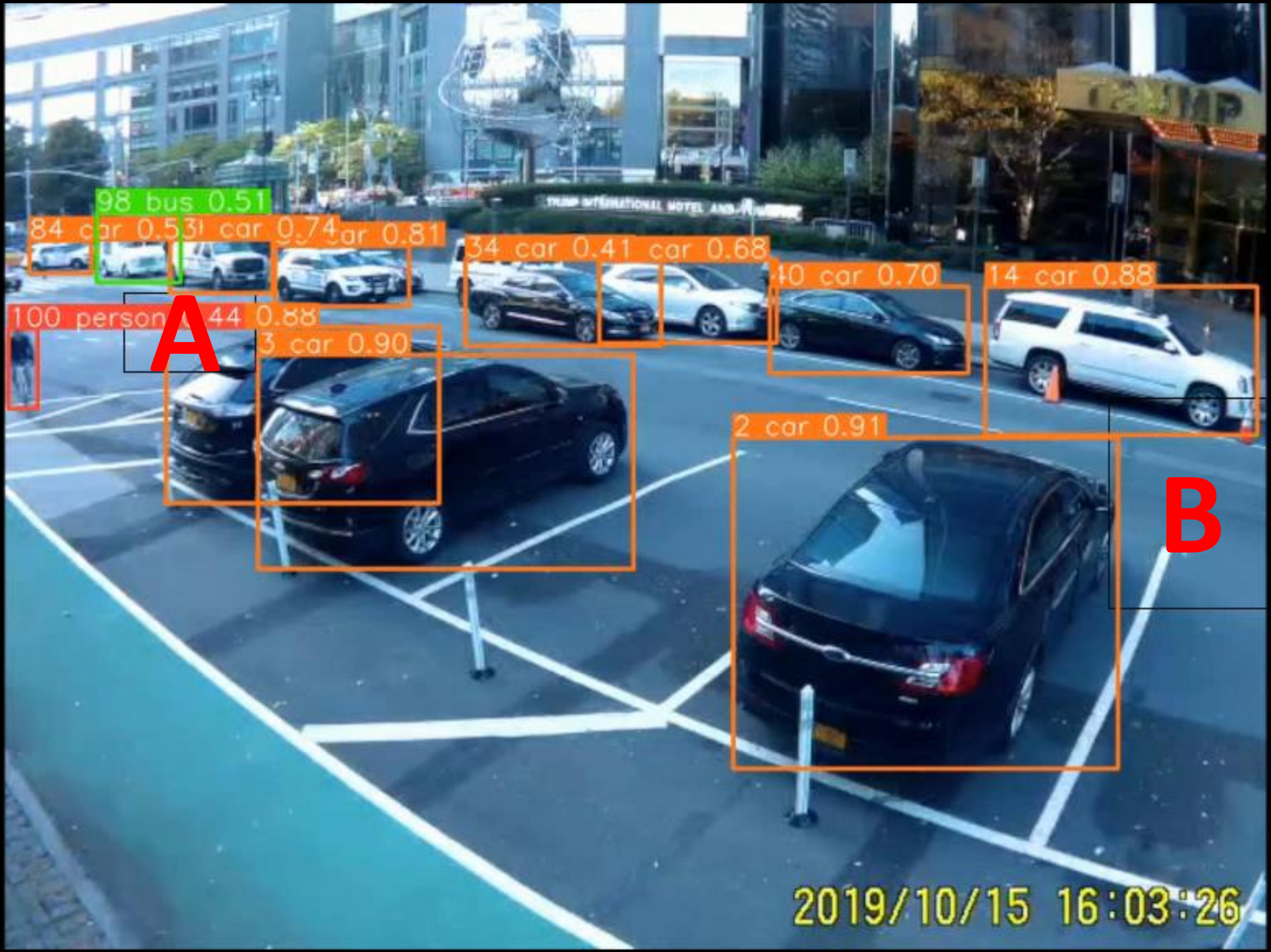


(a) Detect Parking Occupancy

(b) Monitor Bus Lane Usage

(c) Identify Double Parking





Vehicle ID: 35 | Detected speed: 14.44 mph
Average speed/1 minute: 10.33 mph

Video source: NYC DDC

Speed Estimation

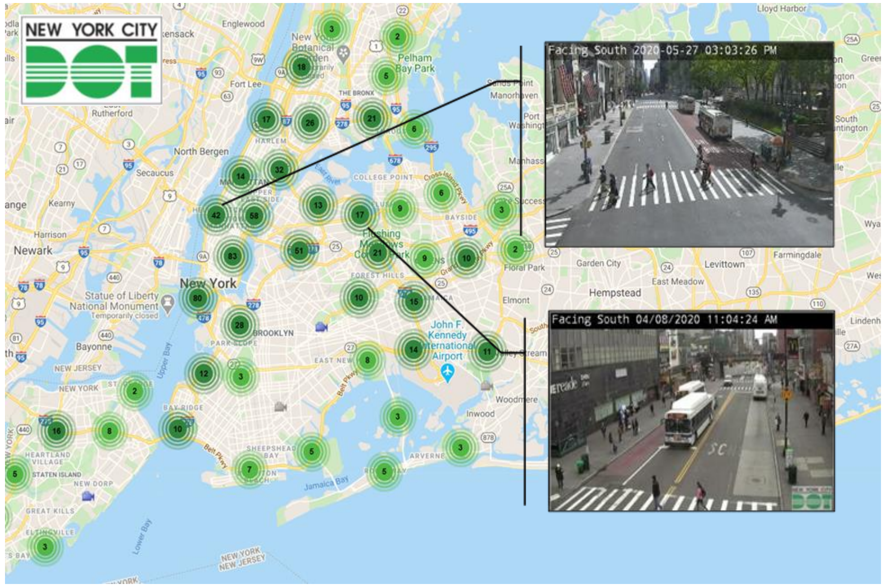
Disaggregated and Aggregated Measures

Speed estimation approach: Projected distance/Detected travel time between two checkpoints

The following metrics can be generated by the algorithm

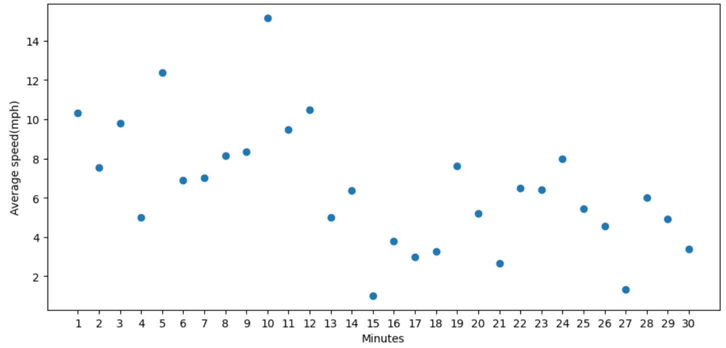
- *Speeding detection, % speeders*
- *Speed estimation for individual vehicle*
- *Average link speed estimation & Speed variations*

- The current NYC DOT public CCTV feeds are discontinuous, this approach can be applied to all 900+ CCTVs in the city if access to the back-office feed with continuous streaming is provided
- Has the potential to fill the gap of non-school zone areas

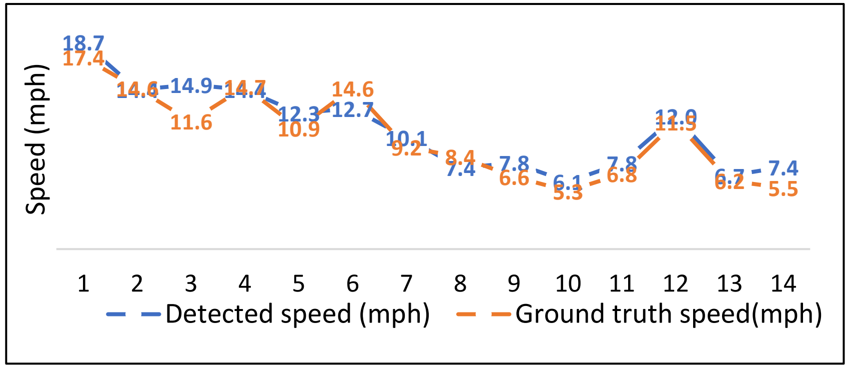


Public Traffic Cameras: https://nyctmc.org/

Average link speed per minute



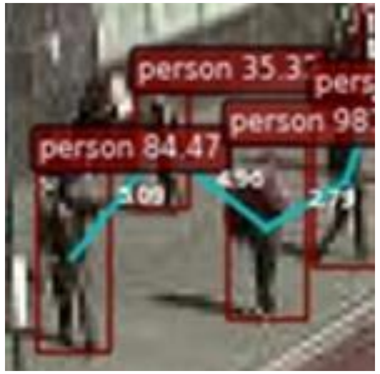
Speed Tracking Accuracy



Performance Monitoring and Evaluation - VRU

Developed apps by C2SMART:

- Pedestrian/Cyclist density & count
- Pedestrian social distancing
- Pedestrian detection with mobility aids
- Pedestrian intention prediction
- Detection with masks - Privacy Protection



Deployment Case Study Highlighted in USDOT UTC Spotlight & ITSJPO Deployment Evaluation Database


UTC Spotlight
University Transportation Centers Program
New York University
U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
Quarterly
Issue 3
July 2021
Using Video Feeds from Public Traffic Cameras and Computer Vision to Analyze Social Distancing and Travel Patterns during the COVID-19 Pandemic

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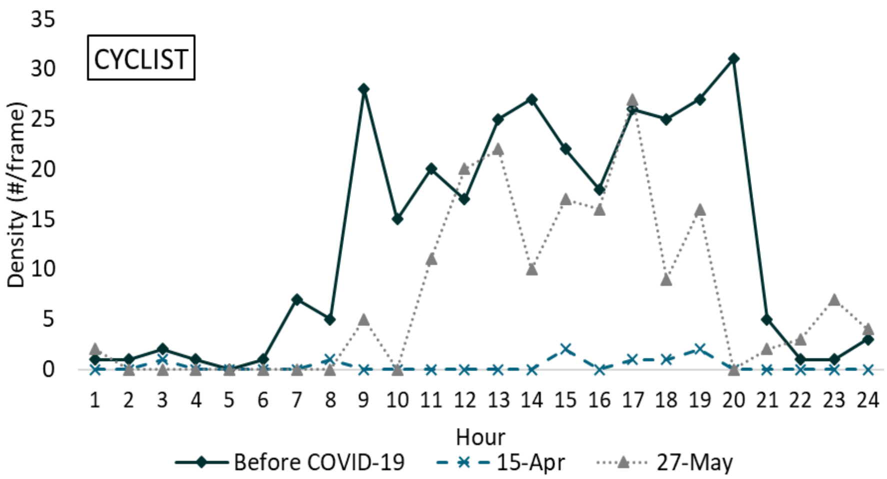
Performance Monitoring and Evaluation - VRU

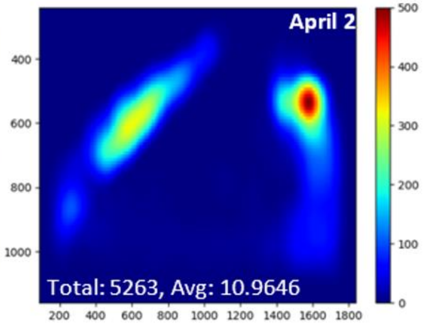
Temporal/Spatial Density Monitoring (crowd density, transit demand (e.g., at bus stops))

Identify Near Miss Hotspots

Traffic Impact Study

- Generate surrogate safety measures
- Track trends due to incidents or crisis

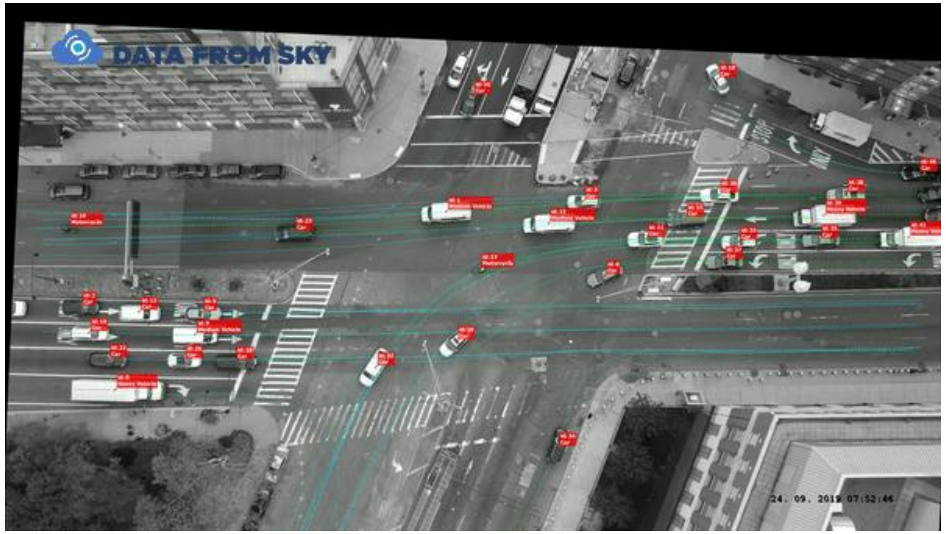


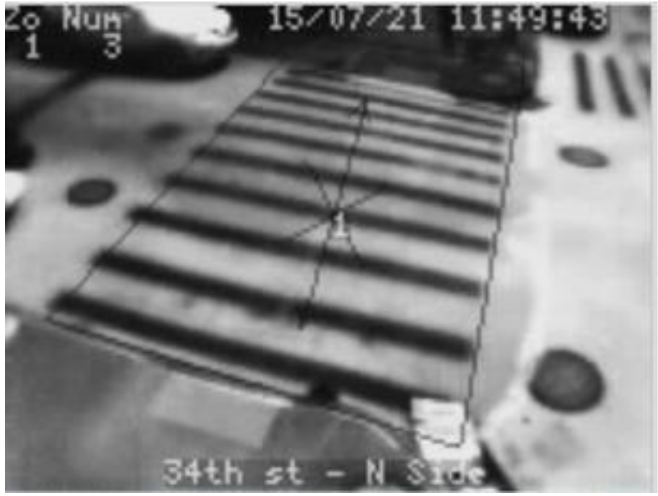


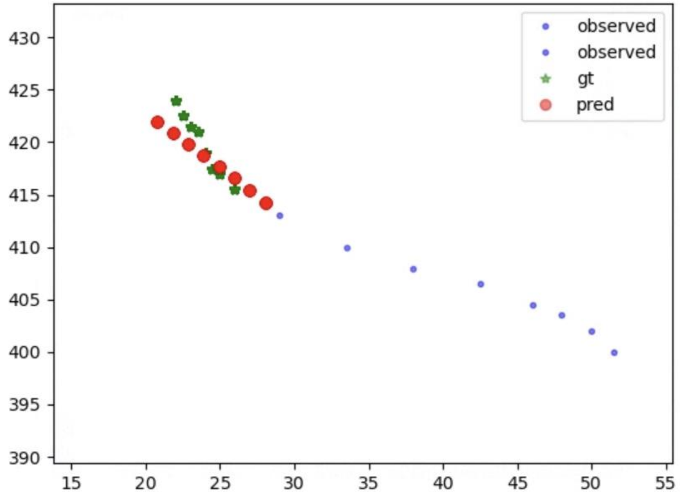
Infrastructure-based Real Time Alert Using Computer Vision

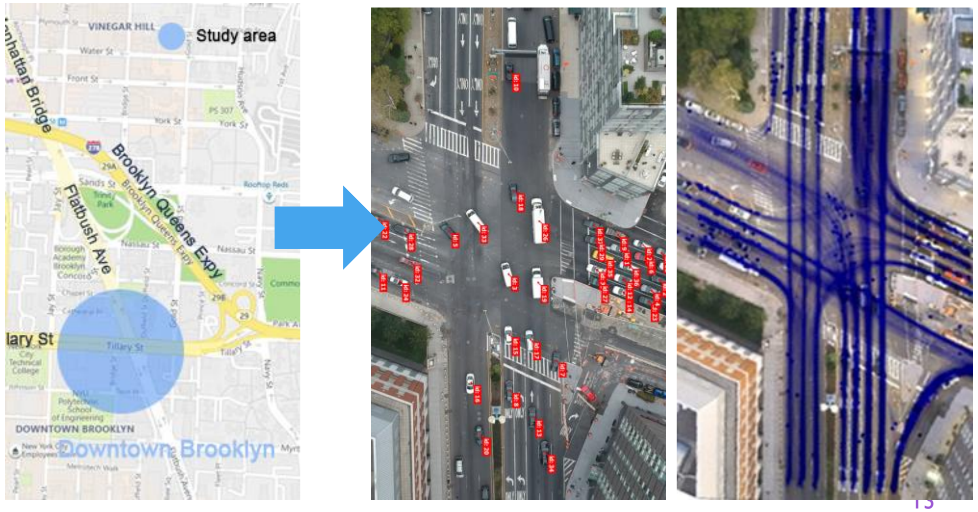
Traffic camera detects pedestrian in crosswalk → I2V → Alert send to turning vehicles

Near misses are detected based on predicted trajectory → I2V/I2P → Alert send to VRU and/or vehicles









Talas, M., K. Opie, J. Gao, K. Ozbay, D. Yang, R. Rausch, D. Benevelli, and S. Sim. "Connected Vehicle Pilot Deployment Program Performance Measurement and Evaluation—New York City Phase 3 Evaluation." US Department of Transportation, Federal Highway Administration. Washington, DC (2021).

New York University C2smart Center, 2019. "Vehicle trajectory data extracted from drone-recorded videos in new york city".

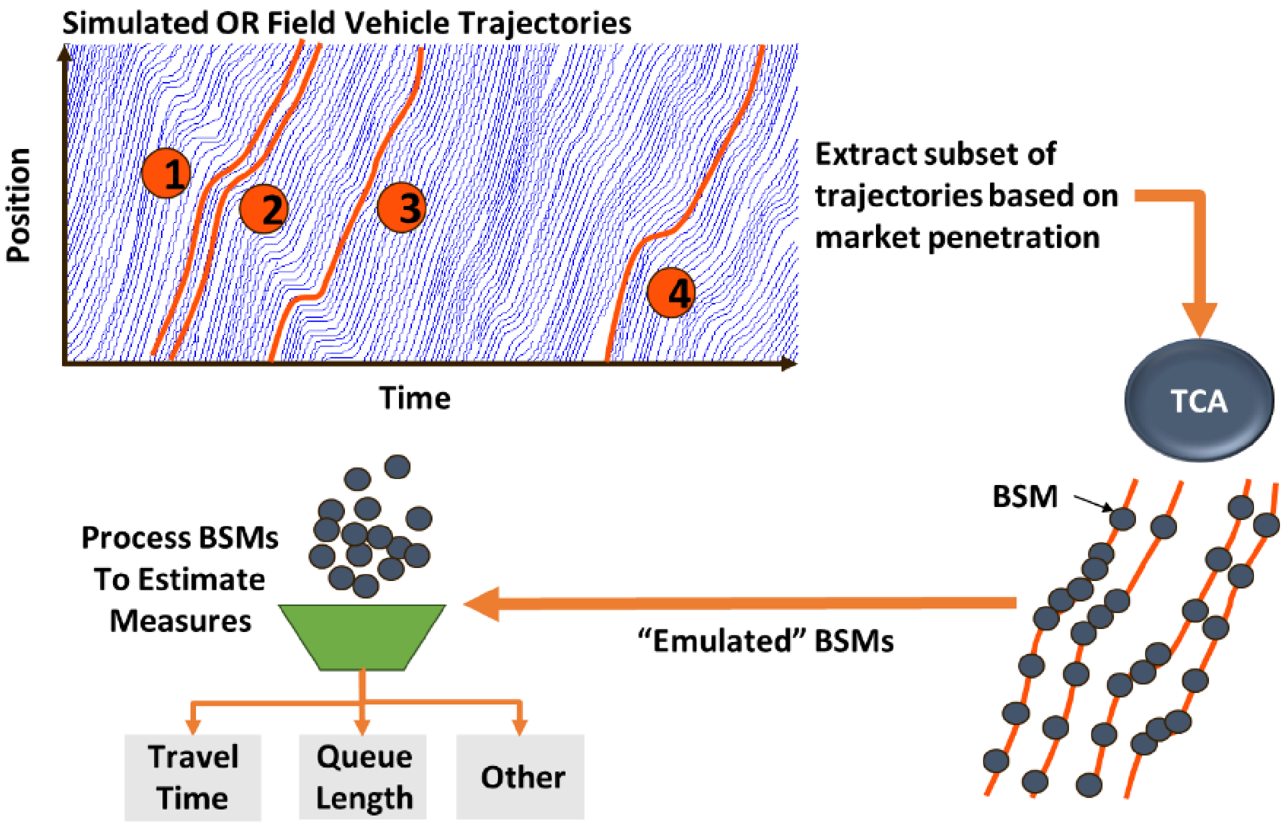
CONVERT VEHICLE AND PEDESTRIAN TRAJECTORY INTO TRAFFIC SAFETY MEASURES

Safety Measure	Definition
Hard Braking (HB)	Hard braking is defined to occur when a vehicle's longitudinal deceleration is greater than a certain pre-determined threshold.
Deceleration Rate to Avoid Collision (DRAC)	DRAC is defined as the minimum deceleration rate required by the following vehicle to come to a timely stop (or match the leading vehicle's speed) and hence to avoid a crash.
Time-To-Collision with Disturbance (TTCD)	TTCD is defined as the time to collision modified by imposing a hypothetical deceleration to the leading vehicle.

Noblis & NYU C2SMART, NCHRP 03-137 *Algorithms to Convert Basic Safety Messages into Traffic Measures.*

Vehicle trajectories obtained from cameras or CVs using Basic Safety Messages (BSM) can be converted into safety measures and has the potential to transform transportation systems management, traveler safety and mobility, and system productivity.

From vehicle trajectories to synthetic Basic Safety Messages to measures



Real Time Alert Based on Camera Mounted on Vehicles/VRUs

Connected Bikes

Bernardes, Suzana Duran, Abdullah Kurkcu, and Kaan Ozbay. "Design, Implementation and Testing of a New Mobile Multi-Function Sensing Device for Identifying High-Risk Areas for Bicyclists in Highly Congested Urban Streets." Procedia Computer Science 155 (2019): 218-225.

Future autonomous driving capability using Crowd-Sourced CAV Data & computer vision

(Source: Mobileye)

Ongoing Collaboration

Town+Gown: NYC

PRELIMINARY EXPLORATION OF VIDEO TRAFFIC DATA ANALYTICS

USDOT University Transportation Center Research

EXPLORING COST-EFFECTIVE COMPUTER VISION SOLUTIONS FOR SMART TRANSPORTATION SYSTEMS

PARTNER WITH US TO ADVANCE VISION-BASED TECHNOLOGY IN THE REAL WORLD!

STRATEGIC RESEARCH

ADVISORY BOARD

INNOVATION LABS

EMPLOYEE DEVELOPMENT

INCUBATION PROGRAMS

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THANK YOU

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Video Analytics and AI for Smart Transportation

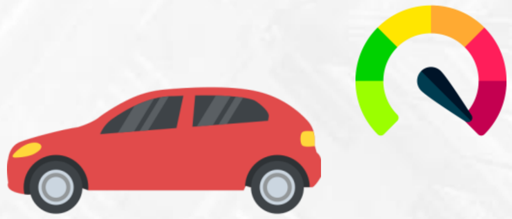
- Using computer vision technology to generate new stream of mobility and safety data is cost-effective
- Capable of utilizing both existing transportation infrastructure (i.e., CCTVs) and emerging probe and CAVs
- Can be customized and localized (e.g., for NYC)

Data Examples

Real-time traffic volume, turning movement count, speed, pedestrian density, walking speed, social distancing, near misses, queue length, lane usage, signage, hazard on the road etc.

Computer Vision App Examples

Speed Detection



Urban Work Zone Detection

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Crowd-Sourced CAV Data

The team will evaluate and test the crowd-sourced CAV information from our industry partner Mobileye, such as near miss events that are triggered by collision warning system, dangerous driving behaviors (harsh braking ratio, harsh cornering ratio), live traffic events (e.g., work zones, hazard on road) and imagery.

Safety

Collision warnings, driver behaviors & road events

Mobility

Vehicle, pedestrian and bicyclist mobility

- Work zones
- Hazard on road
- Double Parking or Stopping vehicles
- Traffic flow
- Pedestrian/Cyclist volume
- Harsh braking
- Harsh cornering
- Near misses

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mobileye An Intel Company

(Source: Mobileye)