Smart Traffic Management into the CAV Era - Telematics, Cooperative Perception, and Digital Twin

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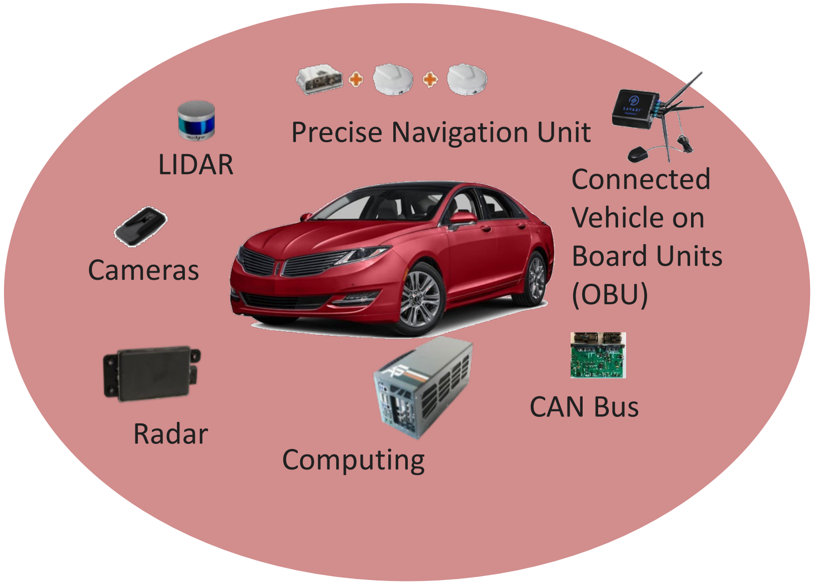
Telematics Data – Vehicle as A Sensor

- Modern vehicles with various sensing, computing, and communication devices
- Real-time telematics data
  - Position and kinematic information
  - Vehicle operation states – fuel consumption, battery level, load level, etc.
  - Environmental sensors
    - Surrounding road users
    - Pavement and asset conditions
- Lab vehicles



Cooperative Perception

- Multimodal sensors - video, Lidar, Radar, etc.
- Multiple data sources – In-vehicle, roadside, aerial
- Sensor fusion, communications, motion prediction

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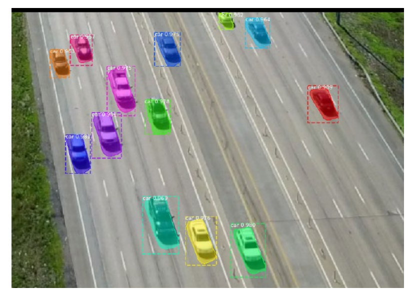

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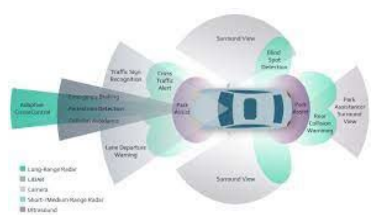

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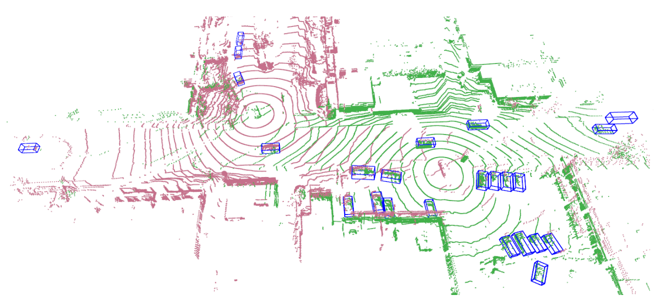
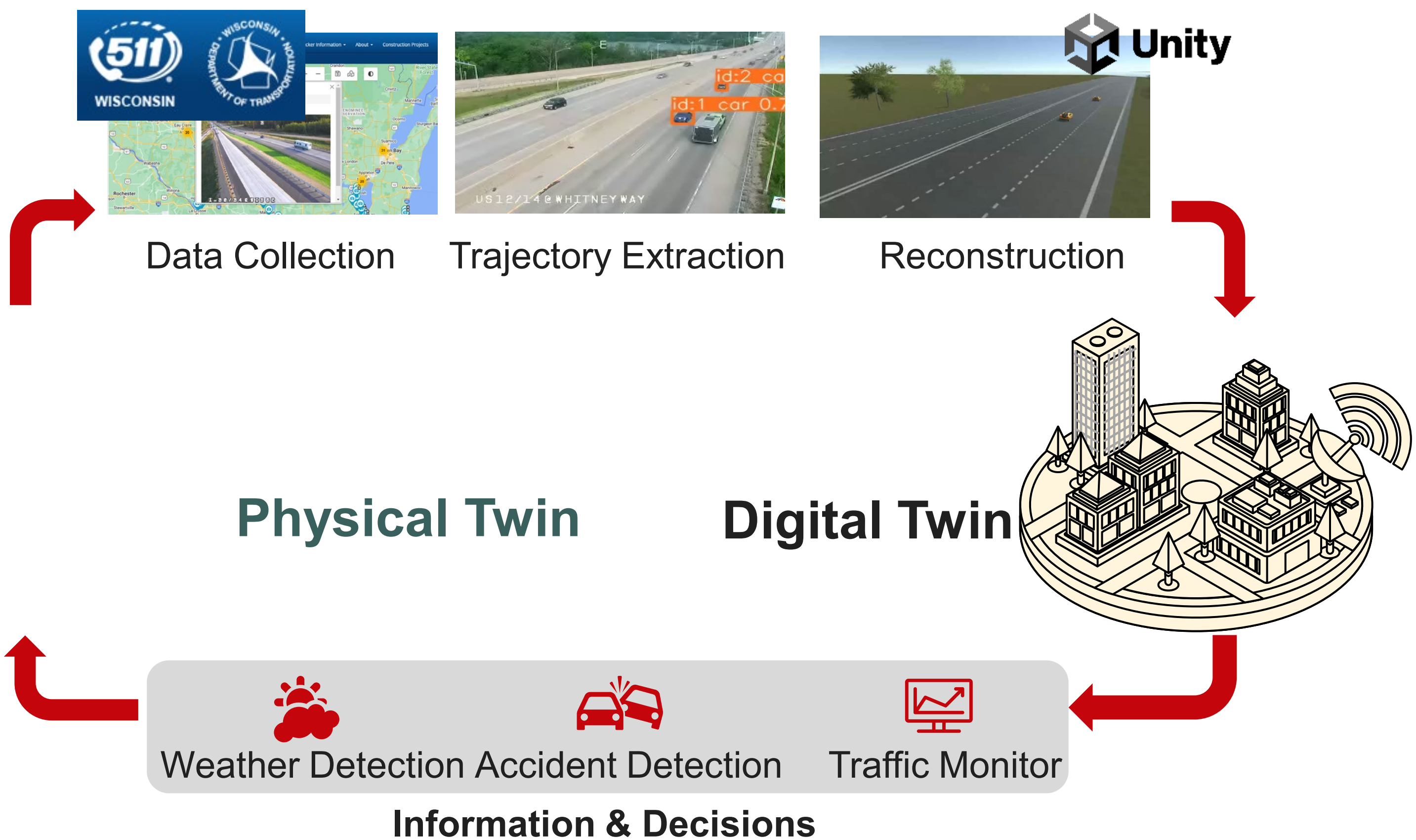


Connected Wise

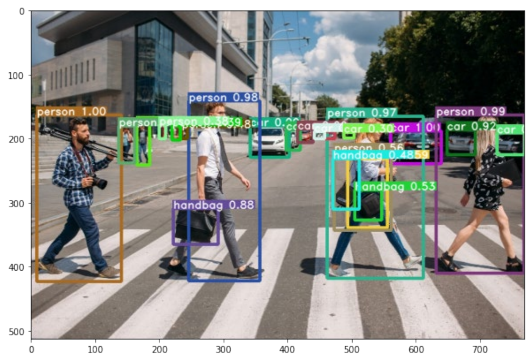
Digital Twin

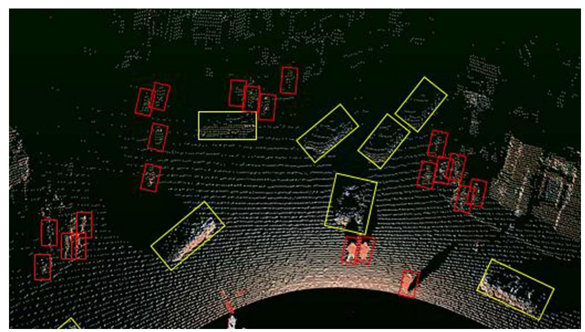
- A digital copy of real word with prediction and optimal decision functions

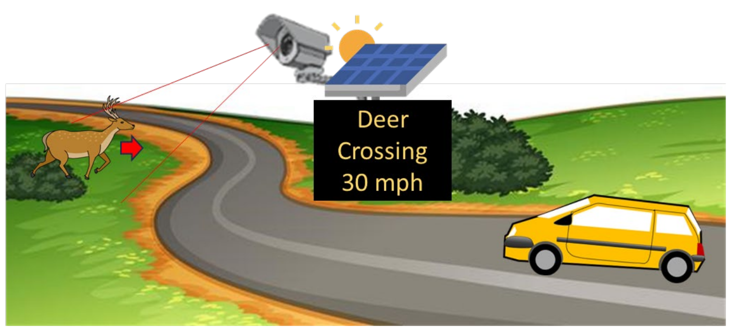


Real-Time Safety Management

- Collision Warning
- Vulnerable Road Users
- Wildlife

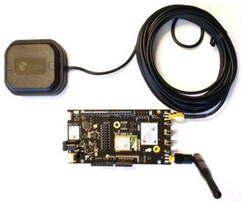




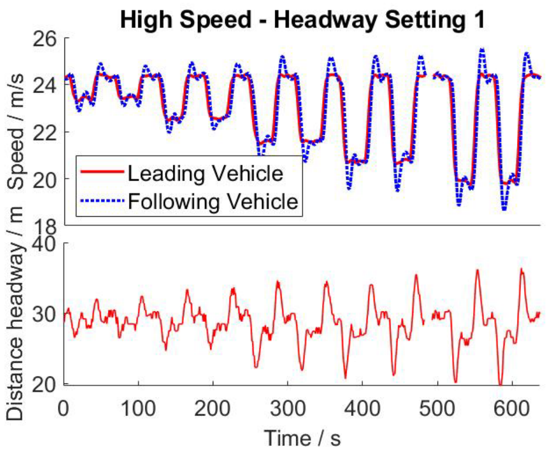


Emerging Technology Evaluation

- Production Automated Vehicles (PAVs) rapidly increase
  - 2% in 2015 -> 10% in 2025 -> 40% in 2040.
  - 92% new cars L1 automation; 50% L2
- Telematics data collected from the PAVs can be used to evaluate and rank their performance on safety, mobility, and energy consumptions

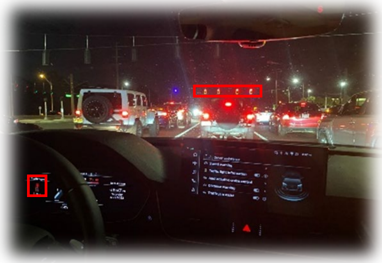


- U-blox GNSS receiver
- Position accuracy: $\pm$0.26 m
- Speed accuracy: $\pm$0.089m/s



AV Sensing and Infrastructure Preparedness

- **Tested functions**
  - **Traffic Light Information (TLI):** Front view camera and GPS data are used to help detect traffic lights.
    - ✓ Some vehicles can accurately detect the traffic light and display its phase; Some vehicles cannot accurately display the right phase and wait time of traffic lights.
  - **Static Message Sign Detection:** Vehicles can use the front view camera to detect road signs; Other vehicles use GPS in combination with a base map.
    - ✓ Sign detection is affected by obstruction, fading, poor lighting, and vehicle speed.
  - **Lane Marking Detection:** Front view camera is used to detect lane markings.
    - ✓ Good detection: Clear markings, straight road, daylight hours; Impaired detection: Unclear markings, curved road, poor lighting at night.

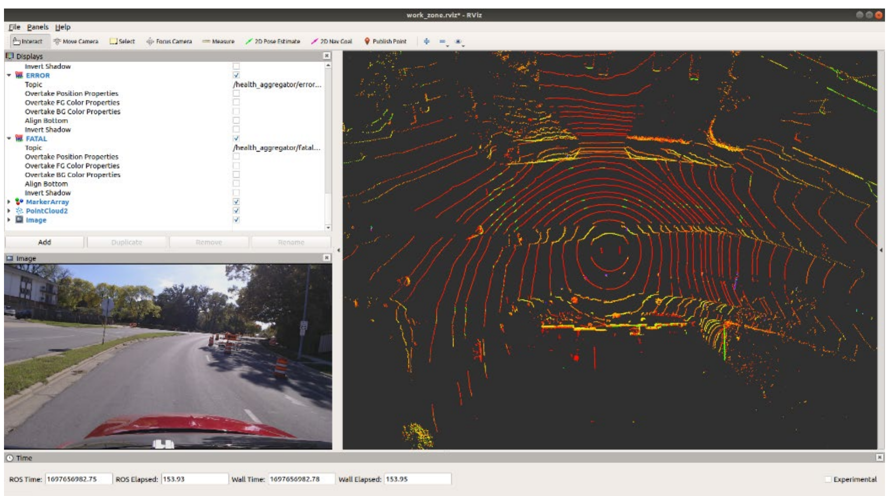


AV Sensing and Infrastructure Preparedness

- **Tested functions**
  - **Collision Avoidance:** Including forward, blind spot, and rear cross traffic collision avoidance, vehicles can use the camera and radar to detect objects.
    - ✓ Works well both day and night for most of the vehicles tested; Forward and rear cross traffic collision avoidance warning distance increases with vehicle speed.
  - **Adaptive cruise control (ACC) with stop & go:** Front view camera and radar are used to help detect and follow the preceding vehicle.
    - ✓ Human-like car-following control (accelerate, brake and maintain speed and distance); Following vehicle can come to a complete stop and then start up if the stopping time is short.

Work Zone Inspections

- Object detection
- Digital information: class, position, identified issues
- Automatic generation of the inspection report



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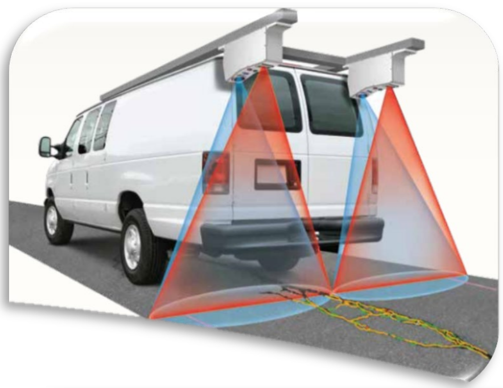
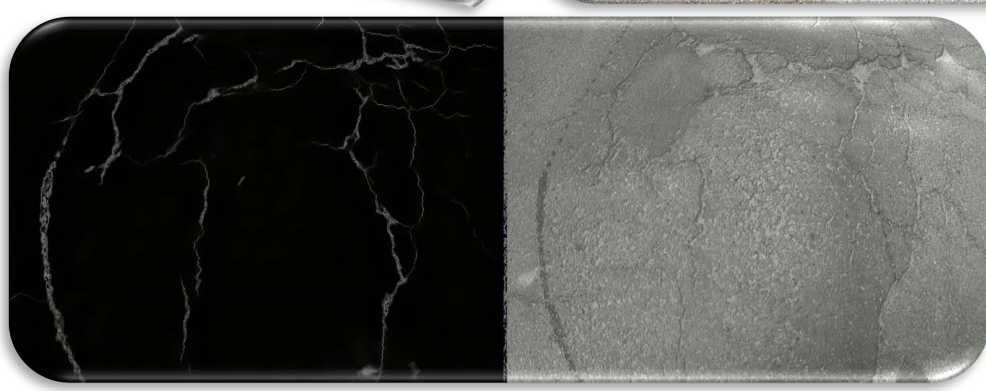
Pavement Inspection

- Expensive professional vehicles → small portable sensors
- High-frequency inspection with crowd sourcing





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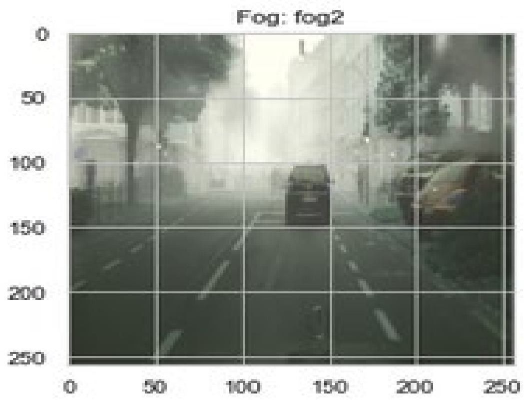
Asset Inspection

- Detect and classify various road assets
- Automatic damage report

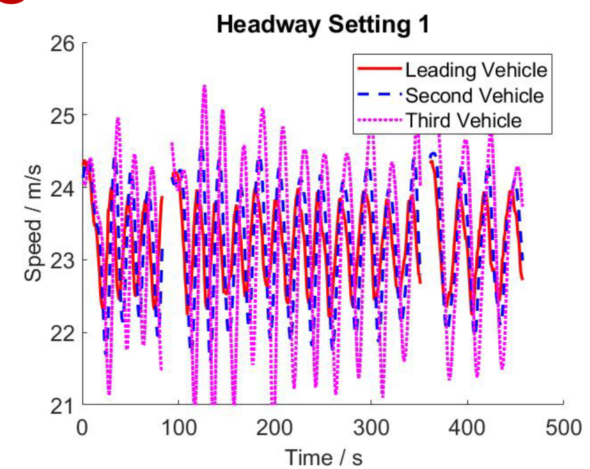
Weather Detection

- Fog detection
- Wet pavement detection
- Ice/snow detection

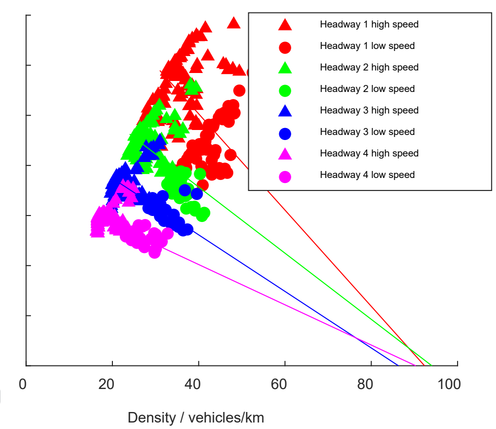


Mobility Measures for Planning

- Vehicle position and kinematic trajectories



- Inference to road capacity, level of services for planning



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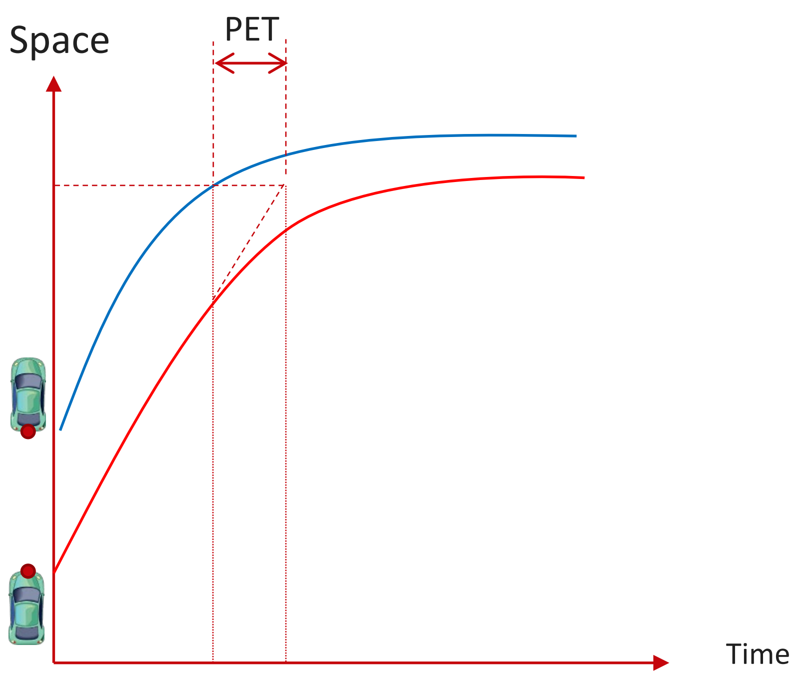
Insurance Pricing

- Telematics data to predict conflict measure and then ultimately predict collision rate



Evaluate EV Fleet Performance

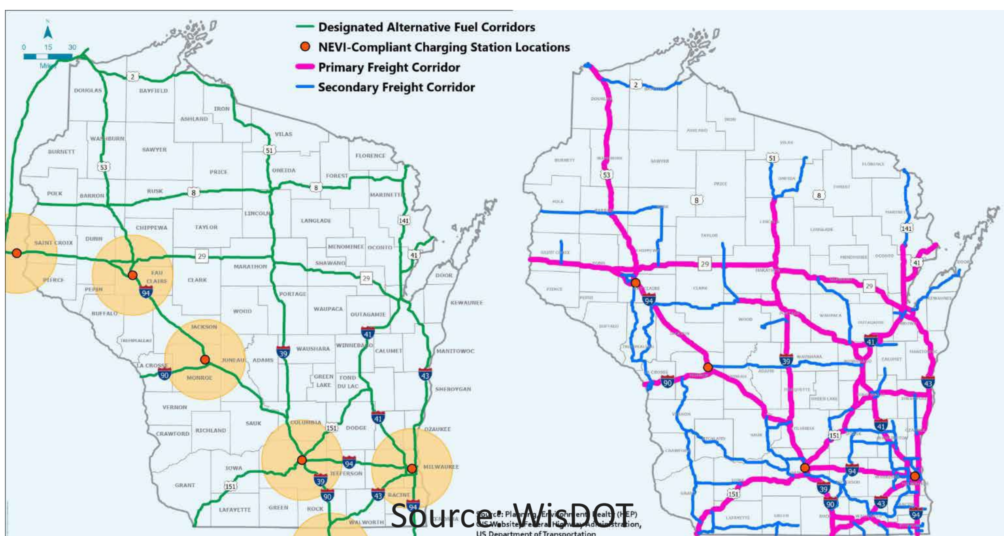
- Initiatives of replacing ICE fleet with E-fleet
- Track E-fleet savings in energy consumption and emissions
- Track E-fleet services in combination with vehicle load

All-Electric Buses in City of Madison

Battery-powered BRT buses begin service in Milwaukee County

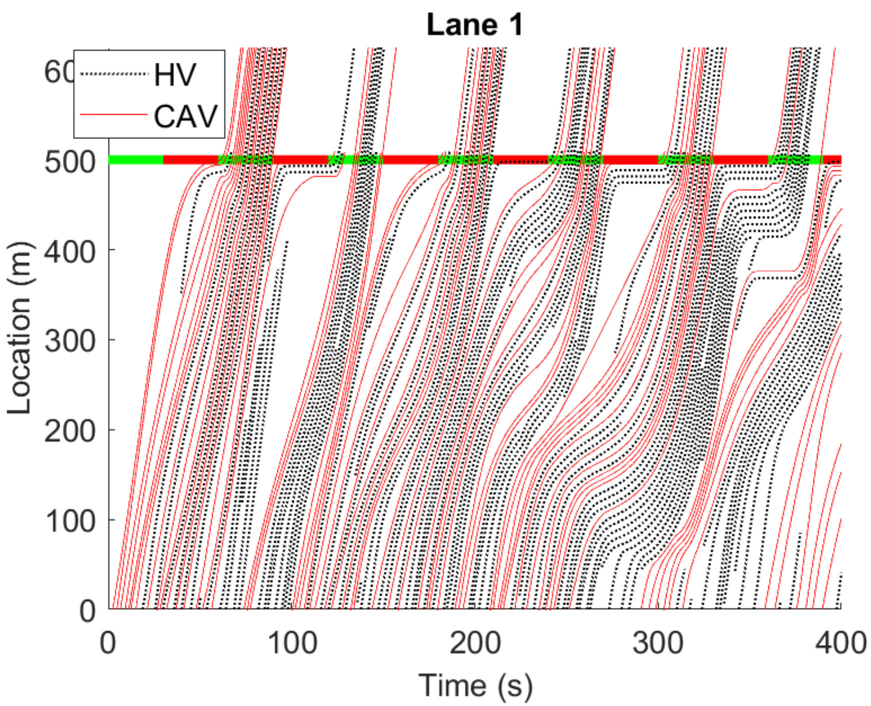
Evaluate EV Infrastructure Performance

- EV Charging Infrastructure Initiatives
  - NEVI, WEVI
- Aggregate vehicle states served by each station to track the station's performance
- Aggregate all stations' performance to evaluate the network performance



Integrated CAV Control

- Detailed approach vehicle trajectory information for better signal timing
- Integrated corridor and management and network control



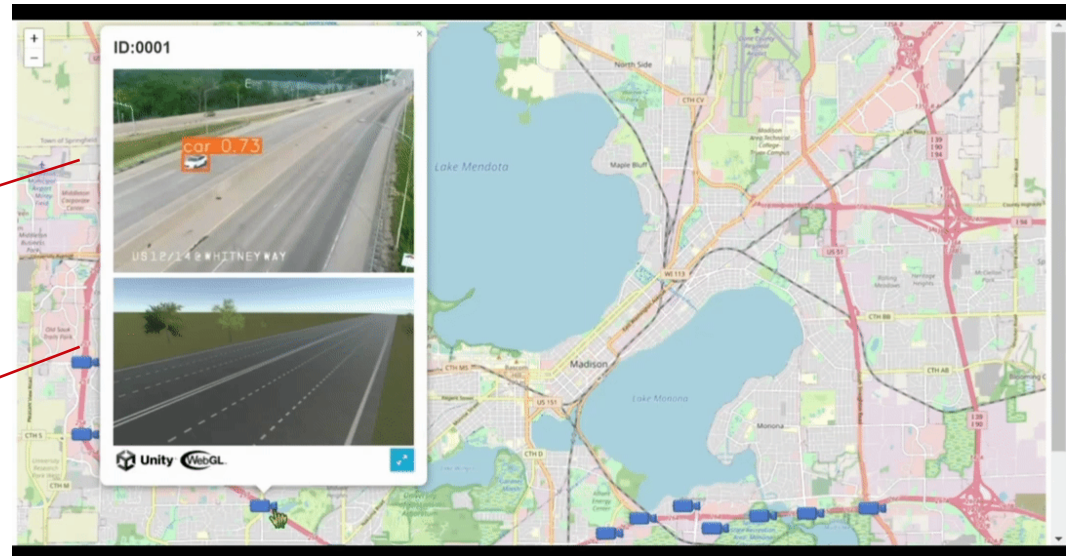
Integrated Digital Twin Platform

- Digital Twin

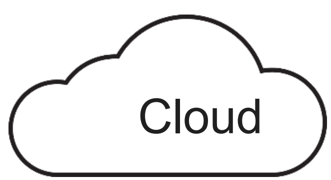
Digital Twin System on the web interface

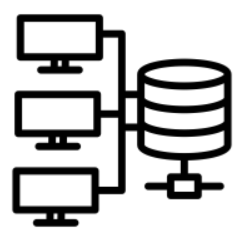
Current traffic states

Digital Twin Model



Edge devices





Distributed Data

Acknowledgements

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Thank You

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