Novel Approaches in Safety R&D: Co-Simulation, AI, Big Data & Computer Vision Applications

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UCF Smart & Safe Transportation Lab

Overview

- AI and Big Data Analytics
- Real-Time Applications
- Computer Vision and Machine Learning Applications
- Multi-driver-in-the-loop Co-simulation platform
- Visualization
- (Pro) Active Traffic Management (PTM)

Safety Prediction

Provide Predictive Insights for Road Safety

New Data & Tools

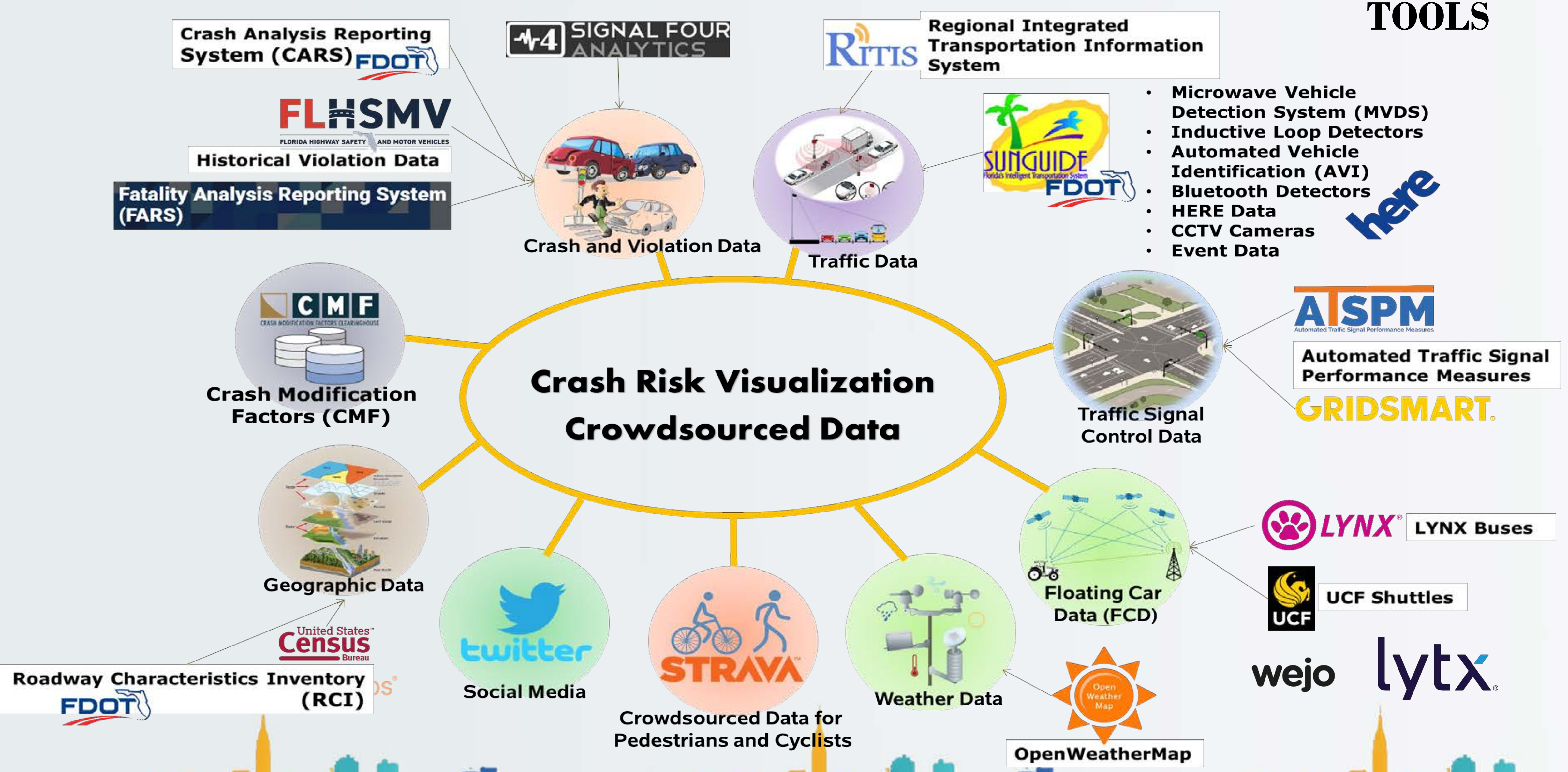
Using AI Techniques & Simulation for Data Collection

Safety Applications

Improvement by Deploying State-of-the-art Technologies

Big Data

DATA-INFORMED
TOOLS

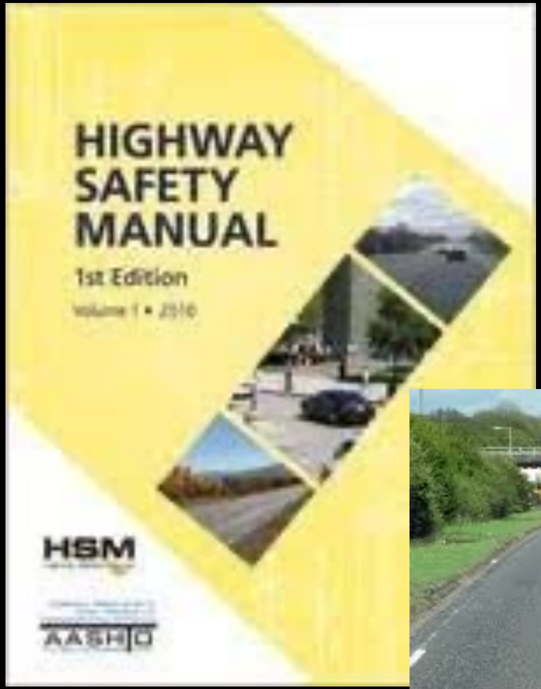


Safety Analysis Data

Traditional Methods

Data

Highly Aggregate Data
Static Data



State-the-art Methods (AI)

Data

High-resolution
Big Data
Real-time
New Data Types

High-resolution Big data in real-time

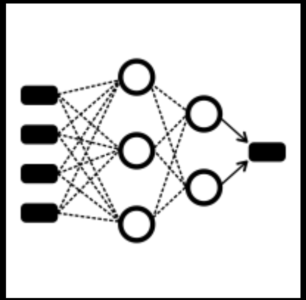
Infrastructure Data
Probe Vehicle Data
ITS Data
Signal Timing
Weather
CAV
Etc.

New Type of Data Sources

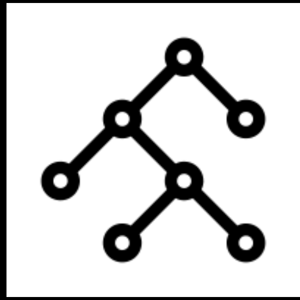
Image
Video
Smartphone
LiDAR
IoT
Etc.

AI applications in traffic safety

Prediction



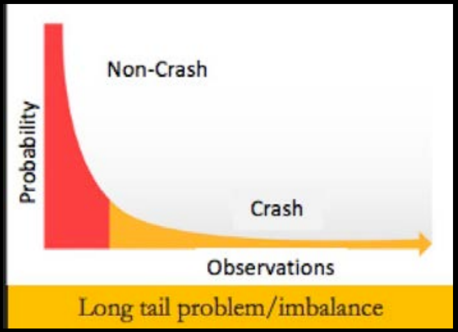
Neuron-based model
（e.g.， CNN, LSTM)



Tree-based model
（e.g.， XGBOOST)

- *Investigate nonlinear relationship between variables*
- *Handle large data*
- *Handle new data sources (high-dimension, time-series*)

Imbalance data issue



Generate Artificial Data
- Generative Adversarial Networks (GAN)
- Variational Autoencoder (VAE)

AI-based Data Collection

Data Sources

- **Emerging sensors:** Camera, LIDAR, Sonar, Radar, UWB;
- **National wide/worldwide data:** Telematics data, CCTVs, Google Street View, Satellite Images, Crash Report

Advantages

- Generate <u>new</u> type of data
- Reduce the <u>cost</u>/improve the <u>efficiency</u> for data collection
- Wide Coverage

Traffic Parameters

Weather

Vulnerable Road User Exposure

New Data

Special Events

Safety Evaluation

Conflict/Near Miss

Road Safety Rating

Crash Severity

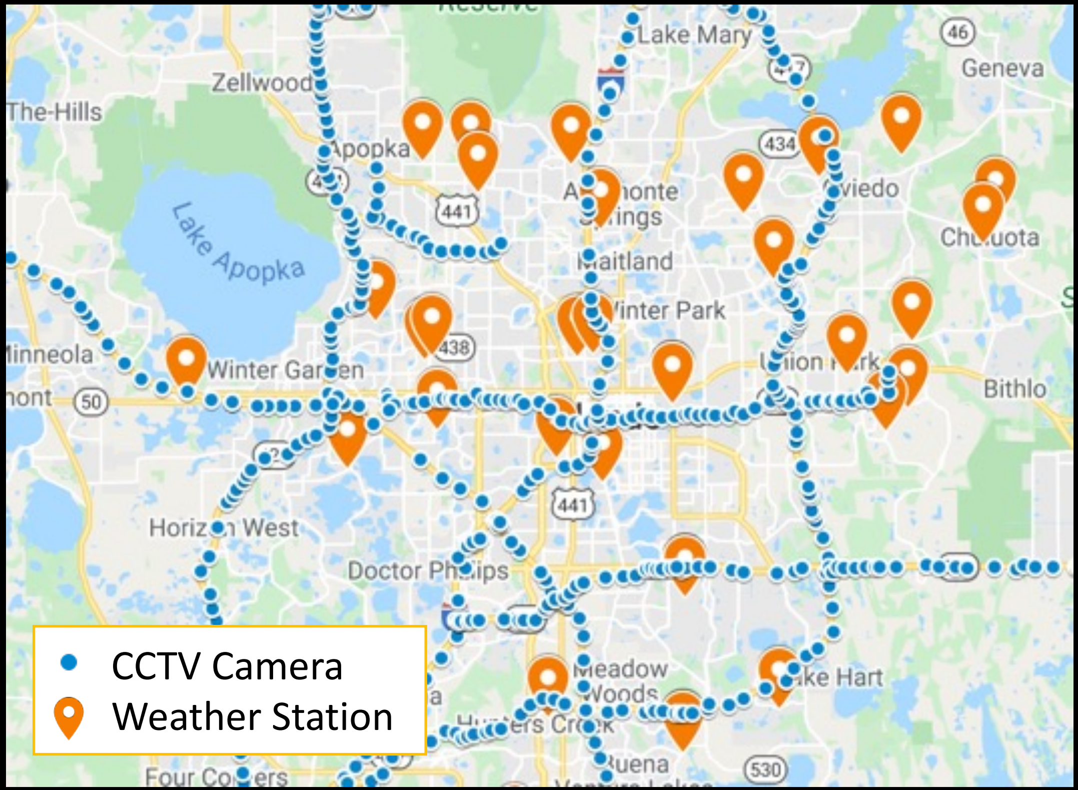
Countermeasure Effectiveness

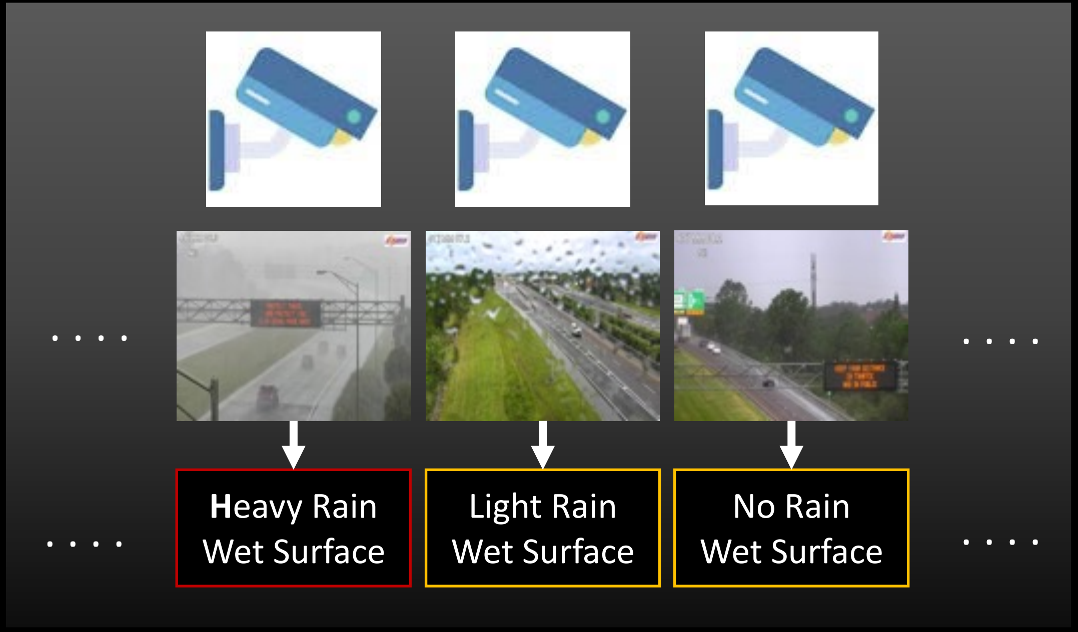
Crash Contributing Factors

AI-based Data Collection

Example: Camera-Based Rain and Road Condition Detection

- Ground weather stations provide accurate measurement of rain but are:
  - sparsely distributed in comparison to traffic cameras
  - not necessarily positioned near roads
  - cannot assess road condition
- CCTV cameras are spaced 0.5mi-1.0mi apart
- Using state-of-the-art computer vision algorithms to detect:
  - 3-level rain condition [heavy rain, light rain, no rain]
  - road surface condition [wet, dry]
- Obtaining real-time, high-frequency, granular observation of rain and road surface condition





AI-based Data Collection

Example: Detect and predict vehicles' maneuvers

Smart Phone

Global Positioning System (GPS)

Cellular positioning

Accelerometers

Magnetometers

Gyroscopes

Modeling

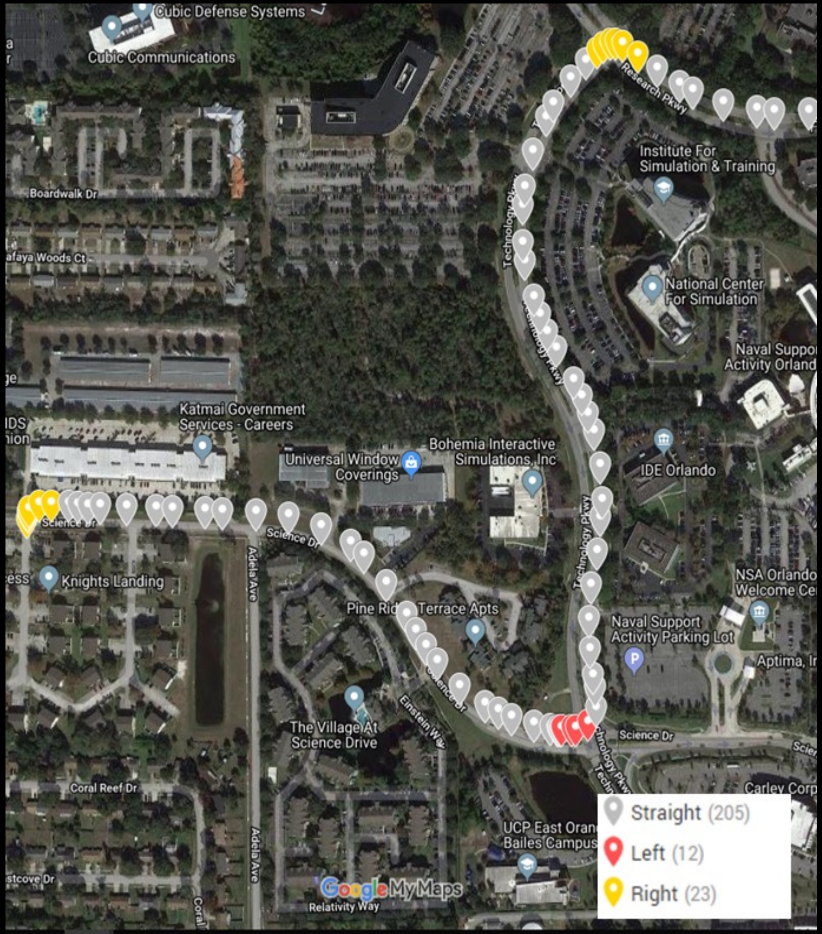
Gradient Boosting

Random Forest

KNN

SVM

- Identify vehicles' movements including left turn; right turn; through; and U turn;
- Random forest method provides the best identification result and could classify vehicles' movement with high accuracy;



An example of classification result based on random forest

Smart Corridor

Sound

Camera

Lidar

UWB

WIFI

Detection

Prediction

Prevention

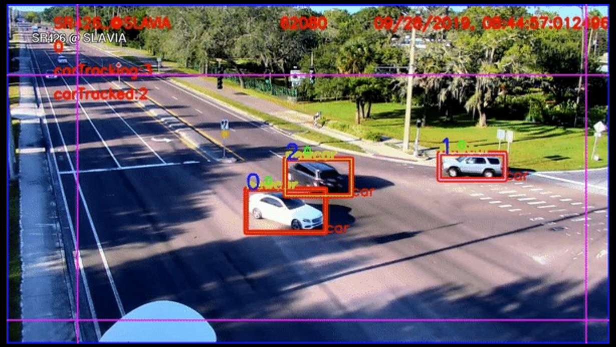
Decision

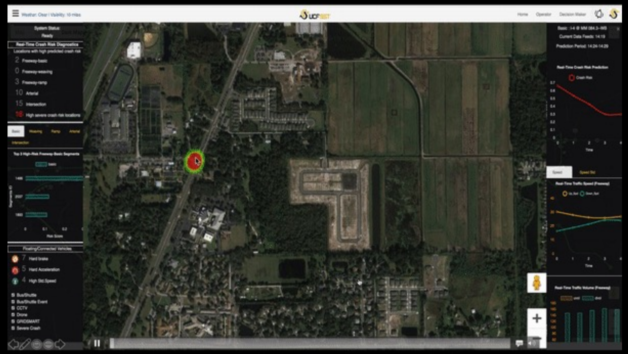
Evaluation

Real-time

Safe

Data Filter





- UCF SST Data Visualization Platform

Precise

Connected

Adaptive

Management platform

- Signal timing
- Count
- Event
- Speed
- Visualization

Warning system

- I2P
- I2V

Sharing

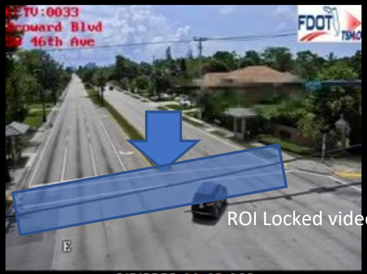
- Data
- Warning
- Event
- Signal phase and timing (SPaT)
- Map data message (MAP)
- Basic safety message (BSM)
- Cooperative awareness message (CAM)
- Collective perception Message (CPM)

Video Data Processing

Data Pipeline

Camera Calibration

Land-Mark



ROI Locked video

6/2/2020 11:46 AM

Input video

Optical flow

6/2/2020 11:46 AM

Detection

One stage

- YOLO
- SSD

Two stage

- MaskRCNN
- Fast-RCNN
- Faster-RCNN

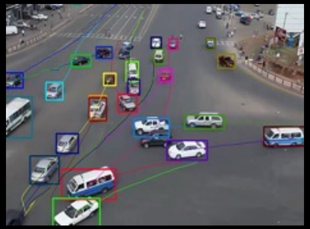
3D pose detection

- openPose
- PIFPAF
- COCO-Pose

Tracking

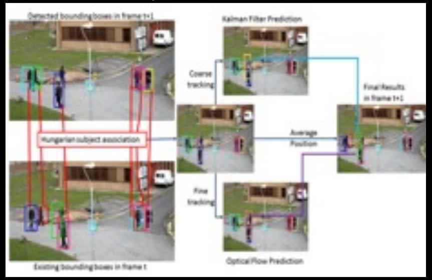
Short term tracking(frame t+1)

- CSRT
- Center-Track



long term tracking(frame t+n)

- RE-ID
  - Trajectory prediction



Traffic Data

- **Volume, Speed & Headway estimation, vehicle classification**
  - Real-time volume, speed estimation
  - Vehicle classification
  - Historical trajectories extraction
- **Vulnerable road user count & speed estimation**
  - Pedestrians & cyclists
  - Intersections
  - Arterials
- **Behavior & Human factors**
  - Crossing behavior
  - Turning behavior
  - Cyclist gesture
  - Age, Gender
  - Pedestrian step analysis
- **Conflict diagnostics based on conflicts of all road users including drivers, ped, cyclists**
- **Abnormal events identification and management**
- **Countermeasure effectiveness estimation/before-after anal**
- **Violation/Events identification (e.g. crash, queue)**
- ***Support first responders***

Automated Roadway Conflicts Identification System (A.R.C.I.S)

UCF SST computer vision platform

ARCIS

This system, applicable in particular to road traffic analysis, uses drone/Unmanned Aerial Vehicle (UAV) videos. The systems can generate the following types of outputs using drone/UAV video data:

- Trajectory data of road users including vehicles and vulnerable road users
- Road users' classification
- Traffic statistics (e.g., volume, speed)
- Safety indicators (e.g., Post-Encroachment Time (PET))
- Active Learning

- DJI Phantom 4
  - 1920 ×1080 resolution
  - 30 FPS
  - 120 feet
  - 23 minutes

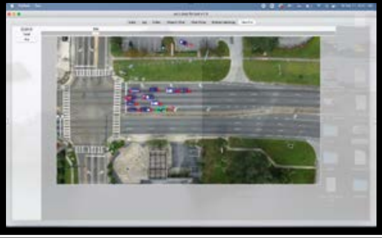
Automated Roadway Conflicts Identification System (A.R.C.I.S)

Video Stabilization

Object Filtering

Video stitching

Data Fix Tool



Google map

Drone Raw Video

Object detection and tracking

Trajectory

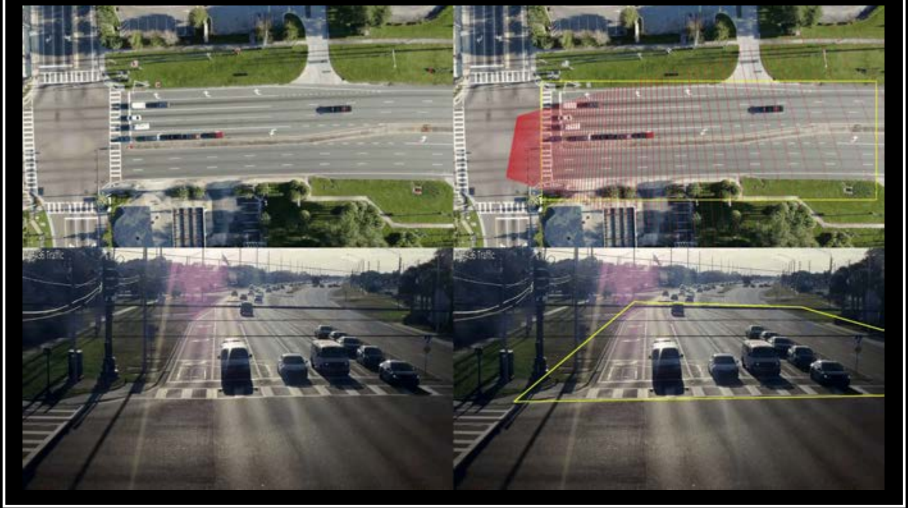
Vehicle occupied location

Car Head/tail

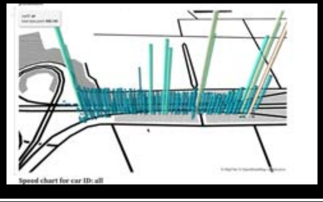
Heading

To GPS Trajectory

ARCIS to CCTV VIEW



Data visualization



TTC

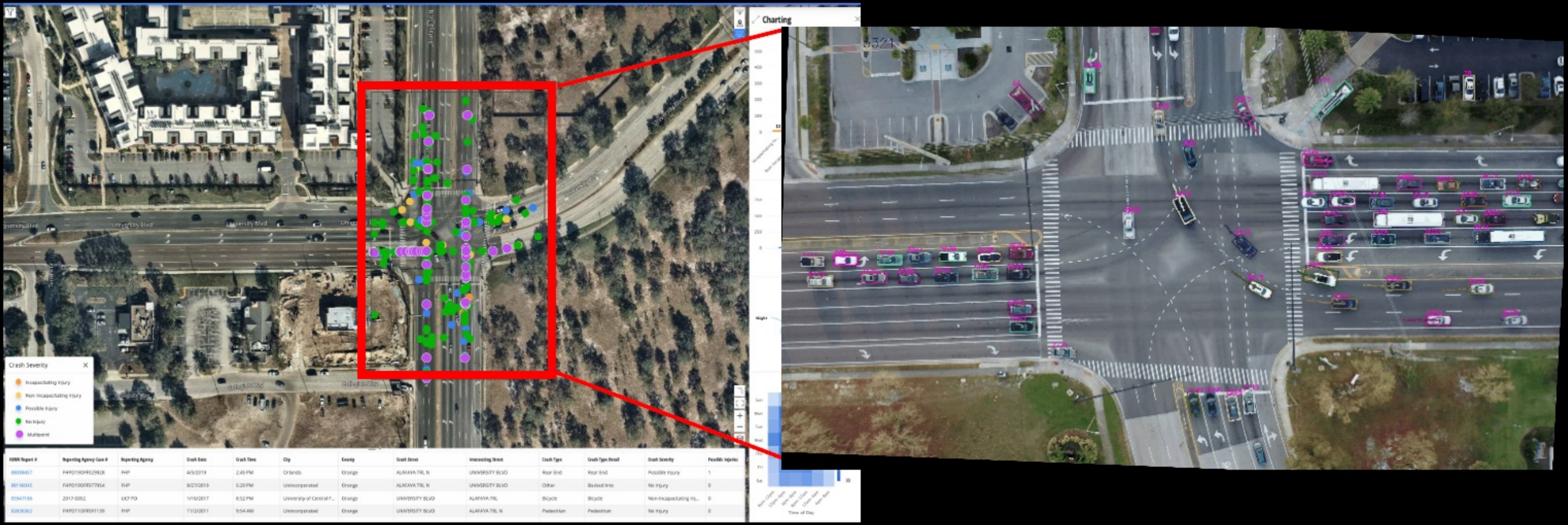
Count

PET

Conflicts

Vehicle Trajectory Output Example

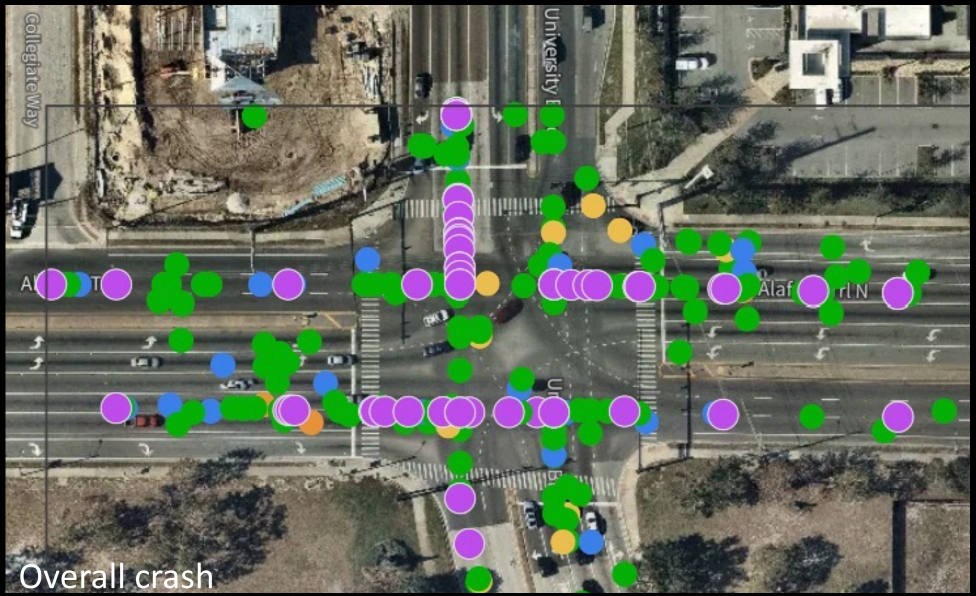
University Blvd@ Alafaya Trail(28.59777019586448, -81.2077834245815)

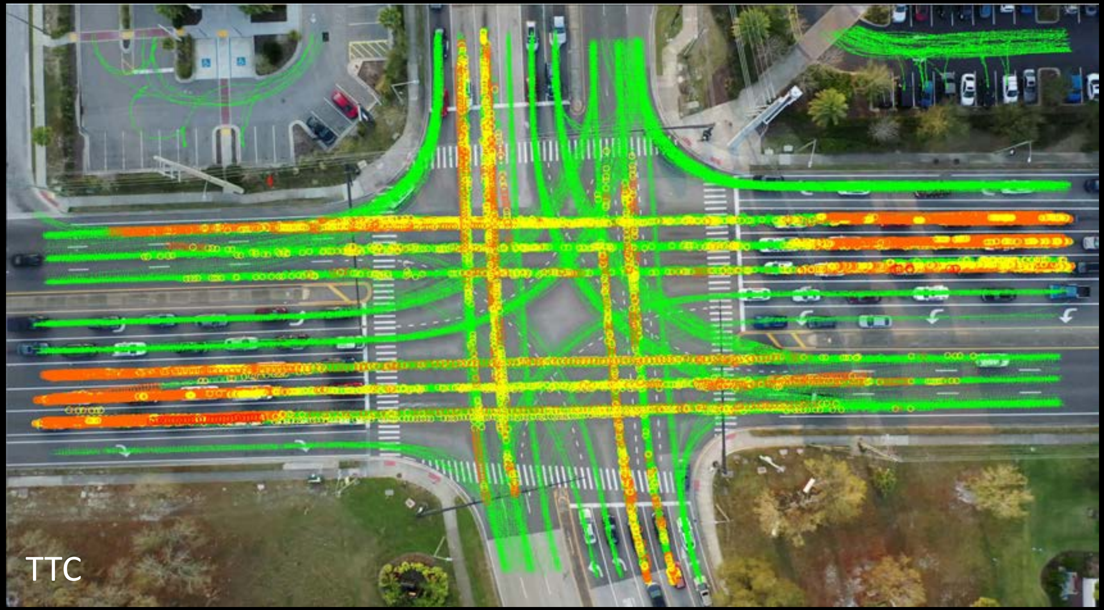


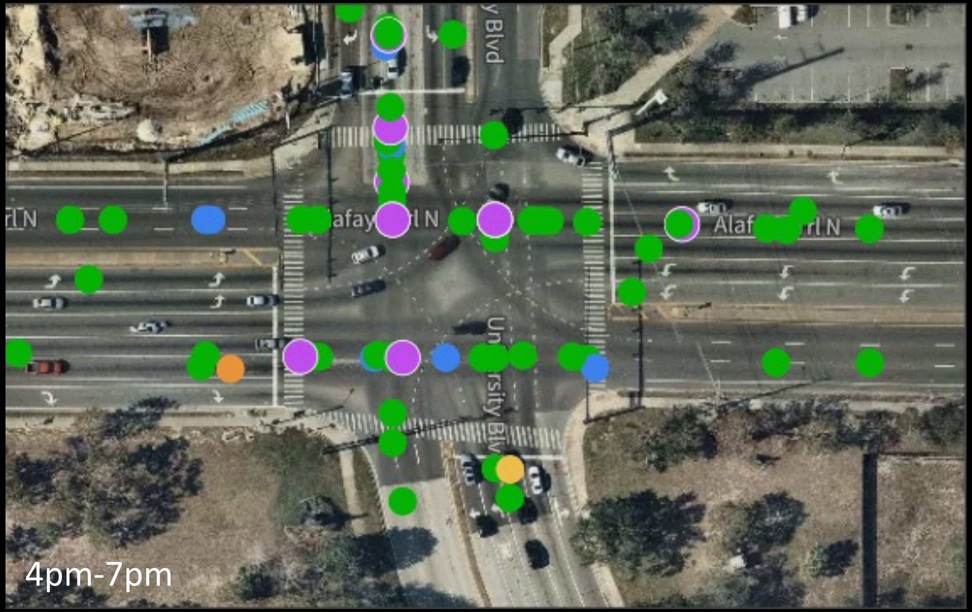
Crash
- 2011-2022
- No Injury:402
- Possible Injury:65
- Non-incapacitating Injury:24
- Incapacitating Injury:12
- Fatal:0

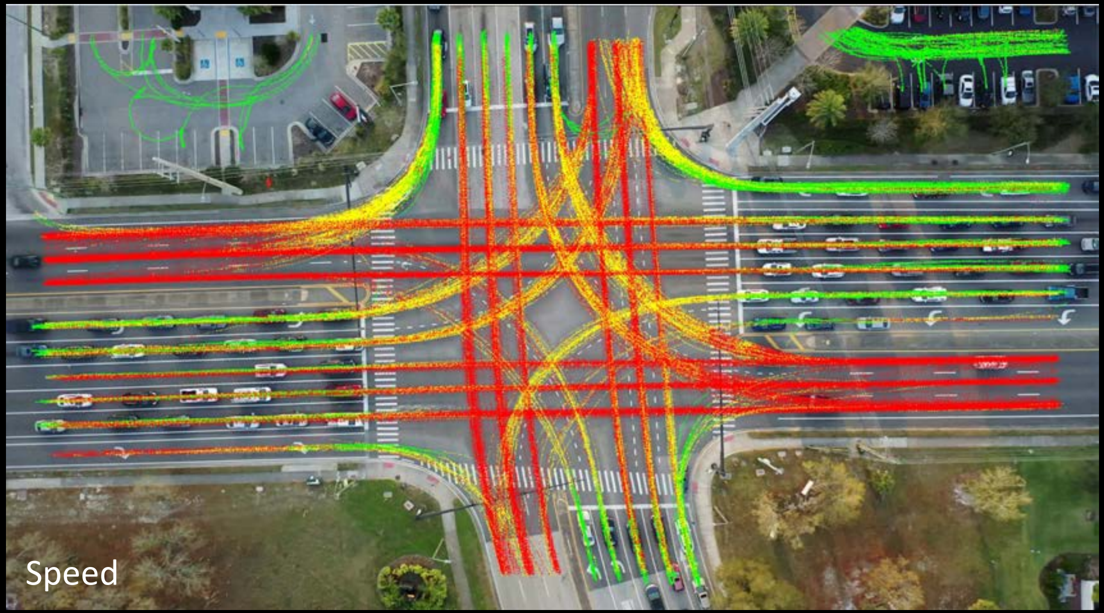
Drone View:
- Queues
- Turning movement
- Plenty merging conflicts

University Blvd@ Alafaya Trail(28.59777019586448, -81.2077834245815)







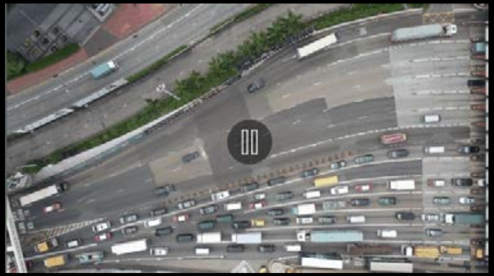


A.R.C.I.S City-Sim Open Dataset

First and largest Digital Twin based drone trajectory open dataset for co-simulation

Signalized Intersection, FL

T-Signalized Intersection, FL



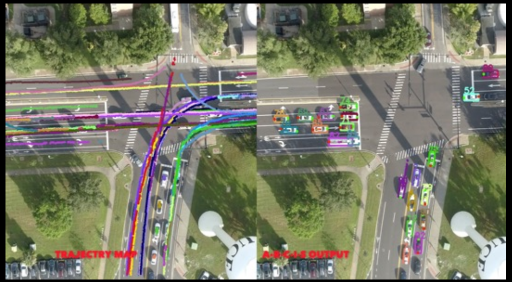
Tunnel entrance-Hongkong

Orlando-USA

UCF-USA

Weaving segment-China

DDI-Sarasota-USA



UCF-Orlando-USA

Non-Signalized intersection ,FL

Digital Twin Model

University @ Alafaya

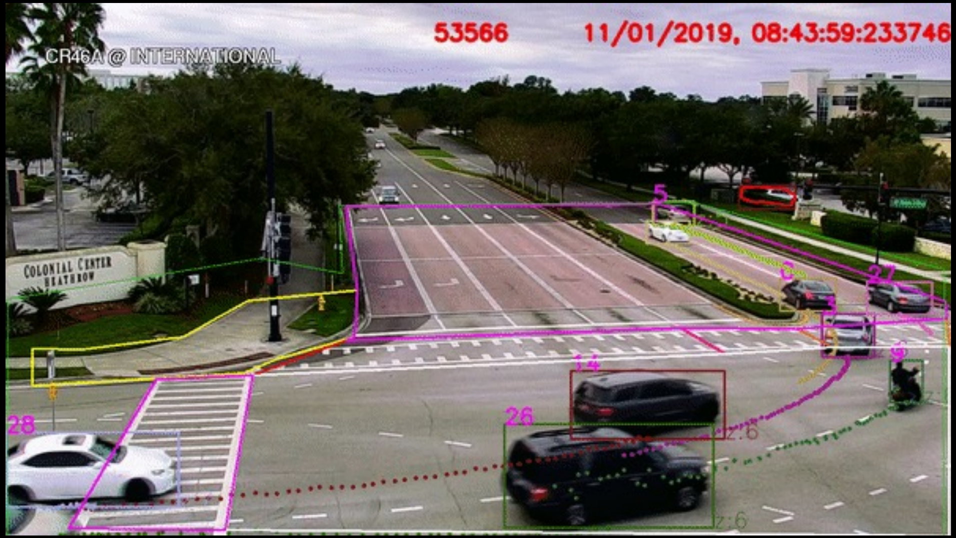
UCF Garage C

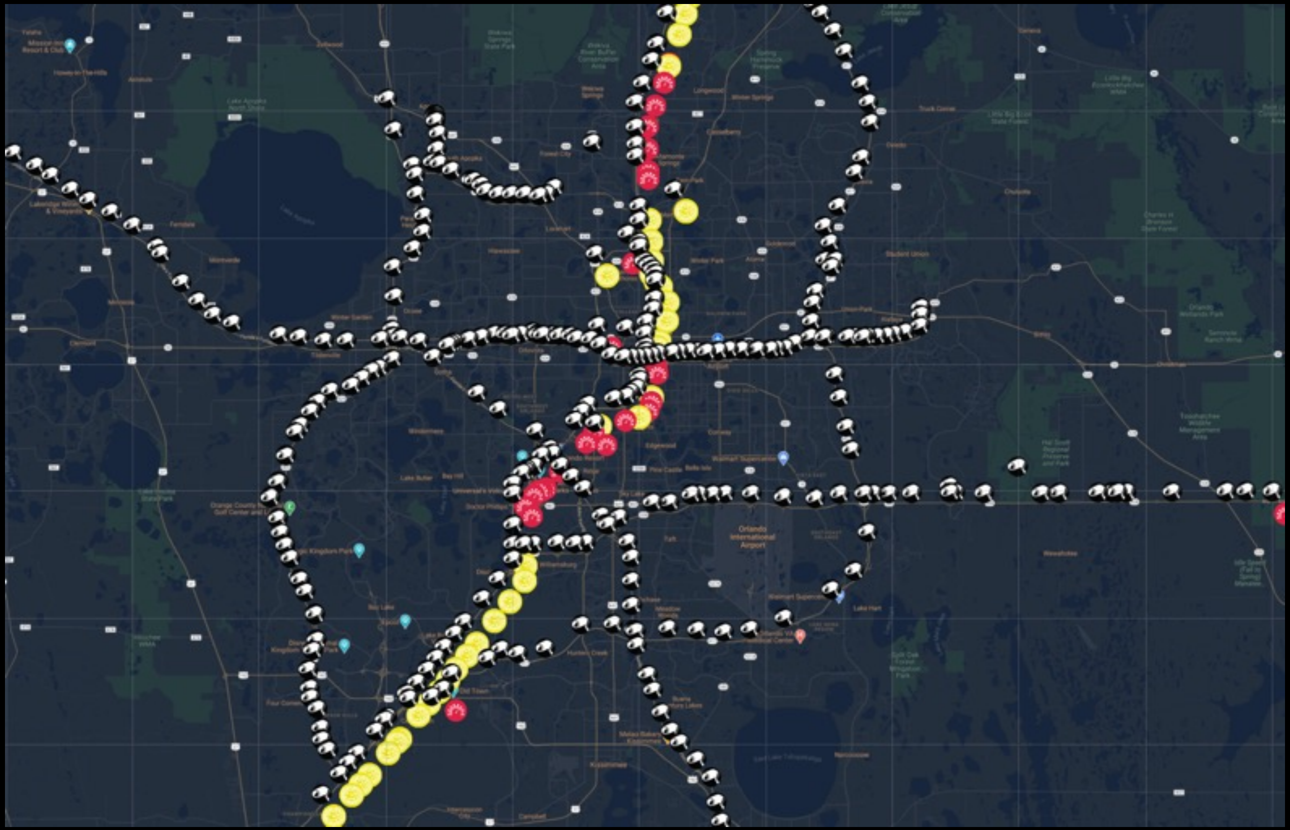
McCulloch

Near Miss Event Detection System (N.M.E.D.S)

UCF SST computer vision platform

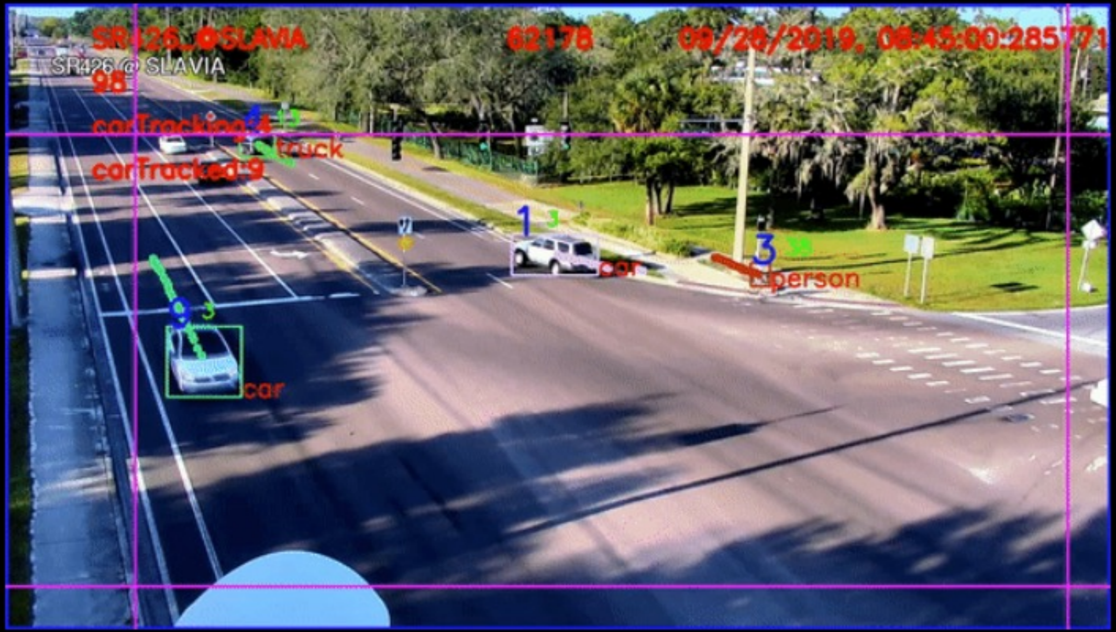
Near Miss Event Detection System (N.M.E.D.S)

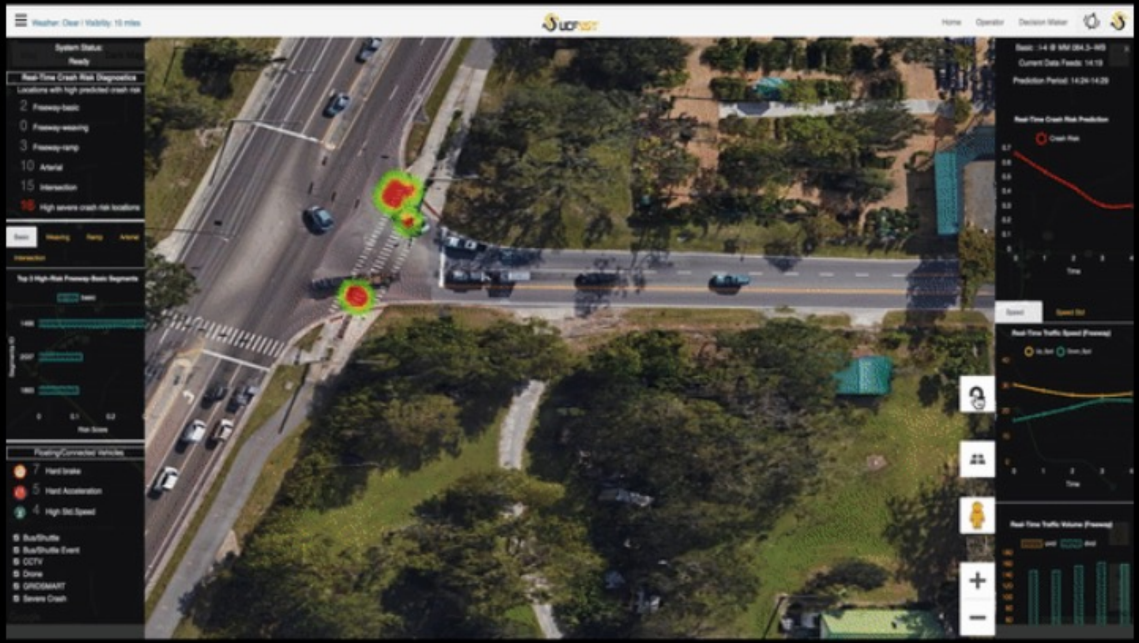




- Over 600 CCTV cameras

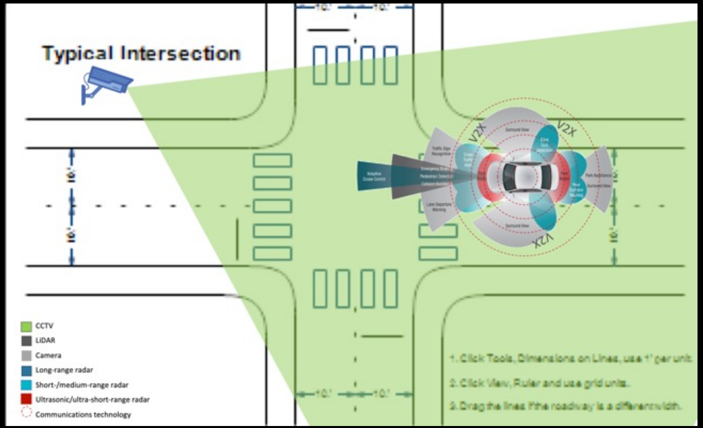
Near Miss Event Detection System (N.M.E.D.S)

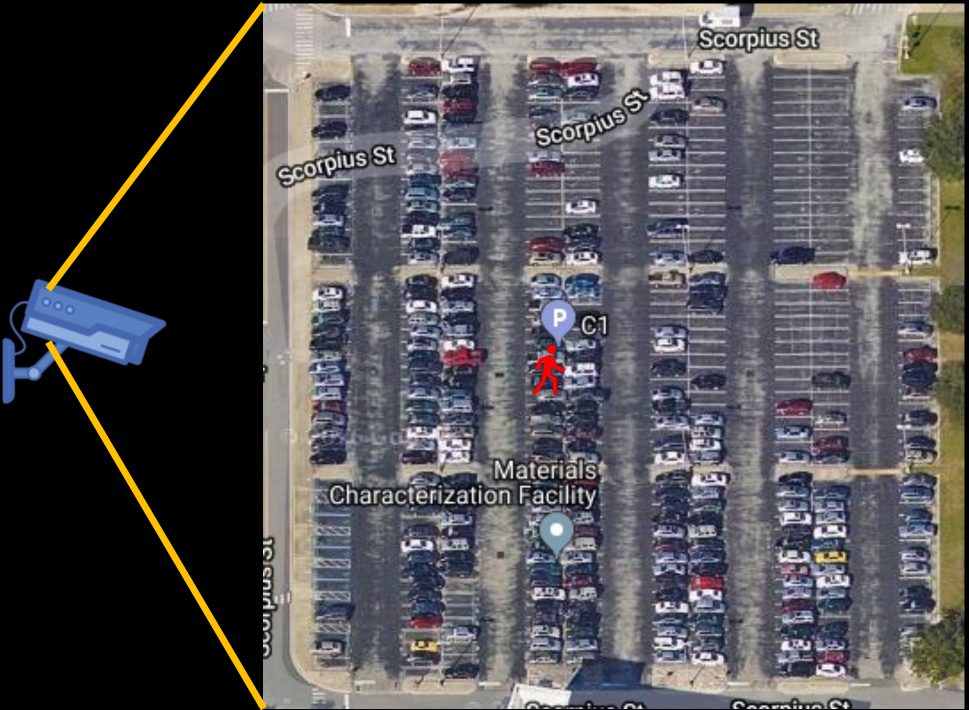




Near Miss Event Detection System (N.M.E.D.S)

I2V



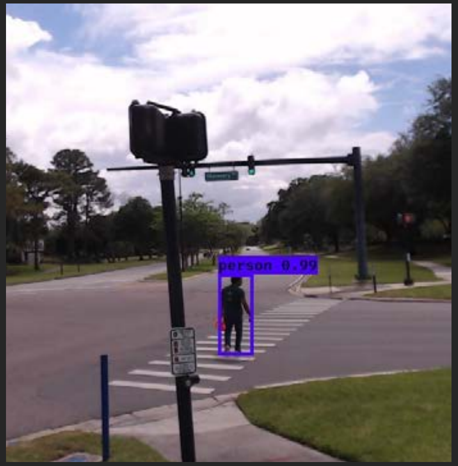


Proactive Pedestrian Detection System

- The evaluation experiments were conducted at three different intersections
- Nearly 1,000 observations were collected for the evaluation
- The results suggested the proactive pedestrian detection system could detect pedestrians in zones of interest with a high accuracy
- The evaluation results also apply to other areas such as segments and other zones of intersections

Intersection Gemini Blvd & Orion Blvd

Intersection Gemini Blvd & Hydra Ln



Intersection Research Pkwy & Libra Drive

A framework of collision warning system

Detection result	Ground truth		Total
	Presence of pedestrians	No pedestrian	
Presence of pedestrians	388	11	399
No pedestrian	79	484	563
Total	467	495	962
Measurement	Sensitivity=388/467=0.831	Specificity=484/495=0.978	-
	Accuracy = (388+484)/ (388+11+79+484) = 0.906		

Prediction of Pedestrian Crossing Intention

Prediction of Pedestrians' Red-Light Crossing Behavior Using Pose Estimation and Machine Learning

Experiment Results

- Four models were developed:
  - Support Vector Machine (SVM)
  - Random Forest (RF)
  - Gradient Boosting (GBM)
  - eXtreme Gradient Boosting (XGBT)
- RF model achieves the best performance with the AUC value as 0.870.
- The model can be further used in the I2V (infrastructure-to-vehicle) system to better warn drivers.

Modeling Results on the Test Dataset

Model (evaluation metrics)	SVM		RF		GBM		XGBT	
	Walking (red-light phases)	Average	**Walking (red-light phases)**	**Average**	Walking (red-light phases)	Average	Walking (red-light phases)	Average
Precision	0.677	0.709	**0.795**	**0.821**	0.806	0.800	0.707	0.754
Recall	0.488	0.651	**0.721**	**0.843**	0.674	0.808	0.674	0.782
F1-Score	0.568	0.675	**0.756**	**0.828**	0.734	0.798	0.690	0.765
Accuracy	0.840		**0.905**		0.886		0.867	
AUC	0.751		**0.870**		0.861		0.843	

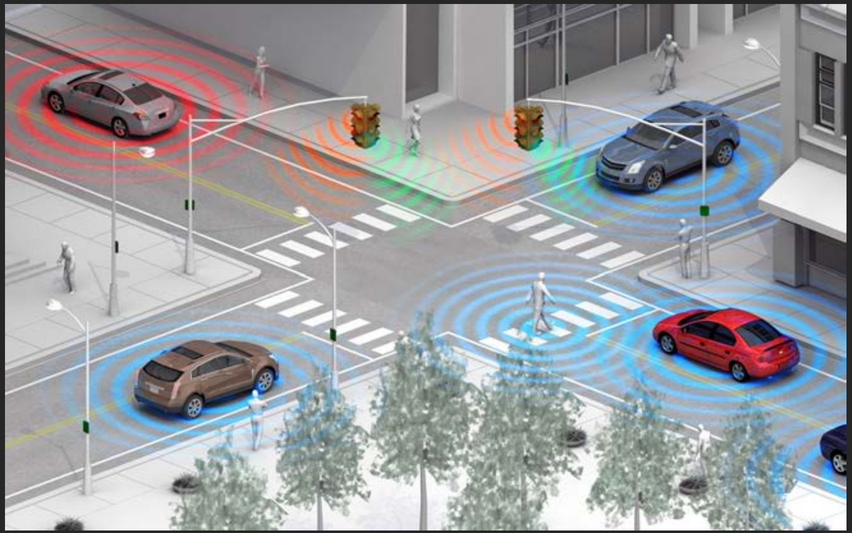


Illustration of warning messages about pedestrians' red-light crossing with the connected vehicle technology

P2V warning – Pedestrians attempt to cross the road at segments

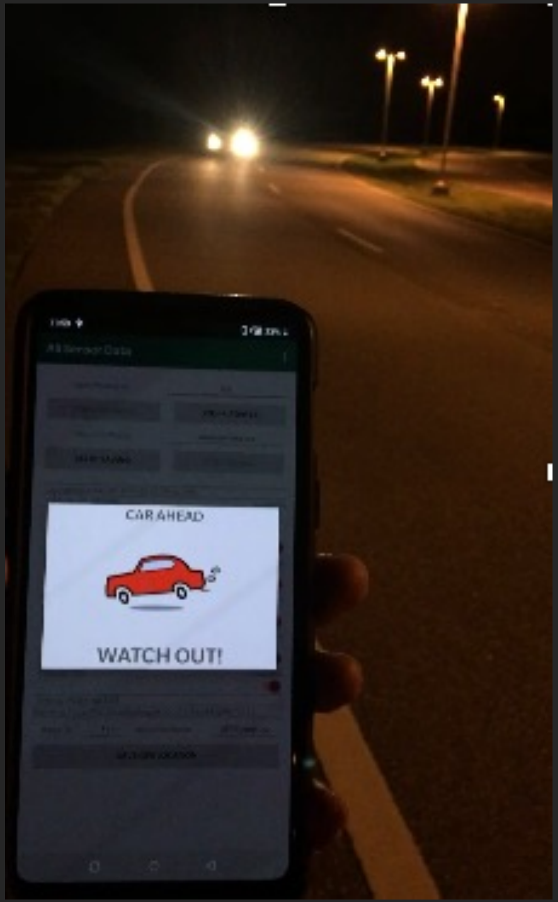
- A pedestrian attempted to cross the road at a segment
- During nighttime, it is difficult for drivers to observe the existence of pedestrians
- Smartphones could send the locations and statuses of the pedestrian and vehicle to the server
- The server determines whether a potential conflict could exist and send the warning to both the pedestrian and driver

Scenario of the conflict between a jaywalking pedestrian and a vehicle

P2V warning – Pedestrians attempt to cross the road at segments (Jaywalking)

- The pedestrian and driver could receive the warning message at the same time
- The driver could receive the warning before he saw the pedestrian

The driver's view



The pedestrian's view

P2V warning – A pedestrian is behind a car

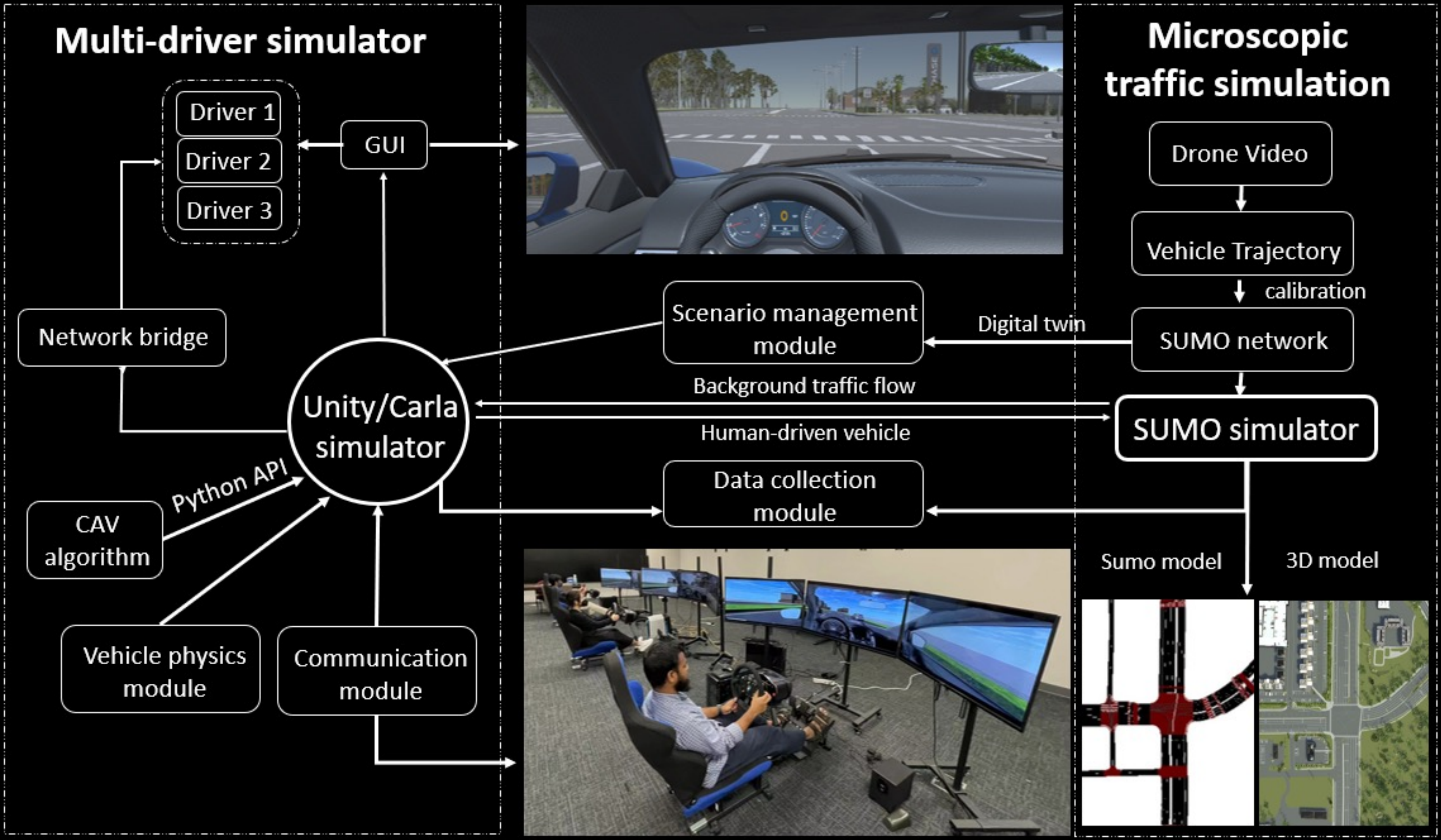
- The driver could receive the warning that the pedestrian ahead who is behind another car

The driver's view

The pedestrian's view

UCF SST Co-Simulation Platform

UCF SST Co-simulation platform



UCF

Two Driving Simulator Platforms

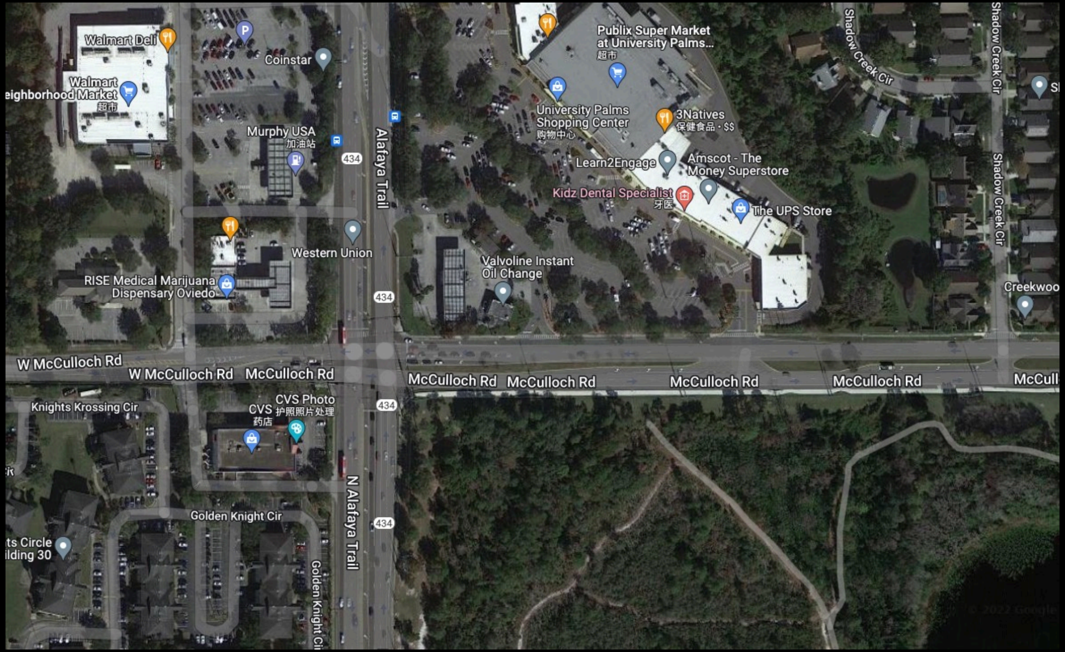
unity

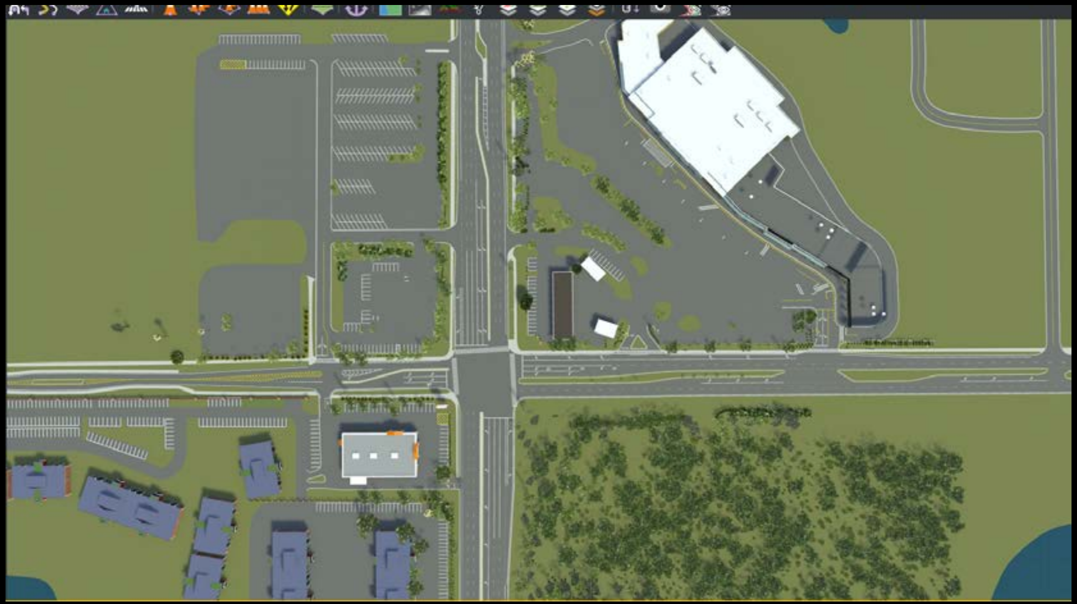
CARLA

Multi-driver simulator

- Connect 3 simulators through network bridge
- Simulators synchronized in real-time
- Cooperative data collection
- Enable vehicle platooning, conflicting, etc.
- Python API for CAV algorithm embedded

Digital Twin base map VS Google map





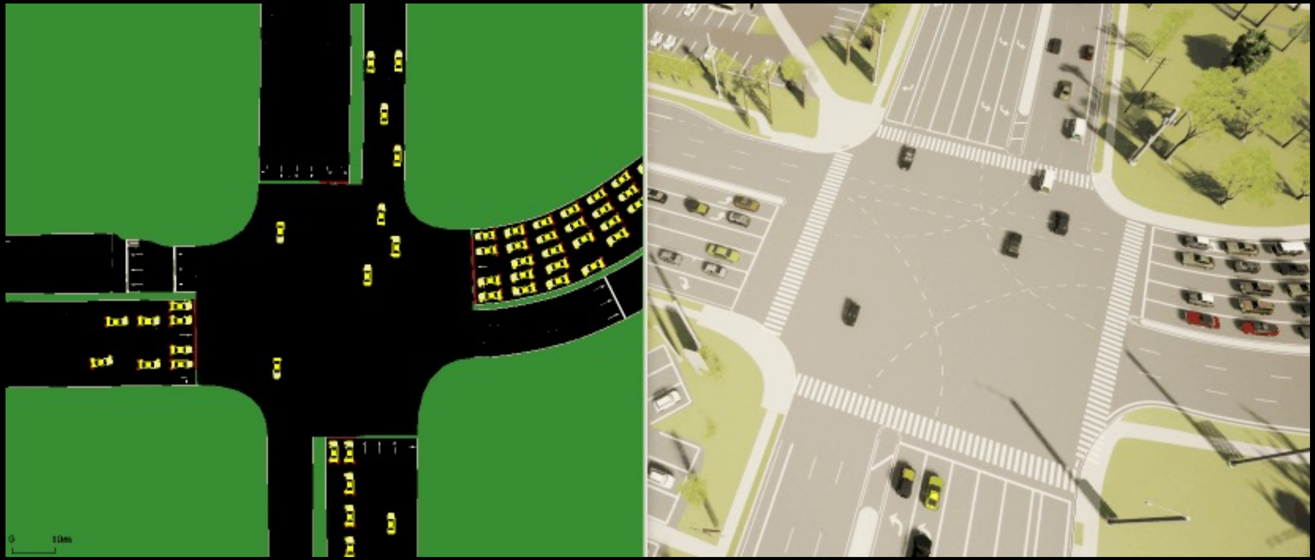
Driving in high-fidelity 3D model

Sumo co-simulation

The role of sumo in driving simulator

- Bi-direction communication and synchronization between Sumo-Carla/Unity
- Generate background traffic flow calibrated by field data
- Provide highly customizable vehicle behaviors
- Enable human-driven vehicle and CAV interaction
- Easier to collect traffic data from Sumo

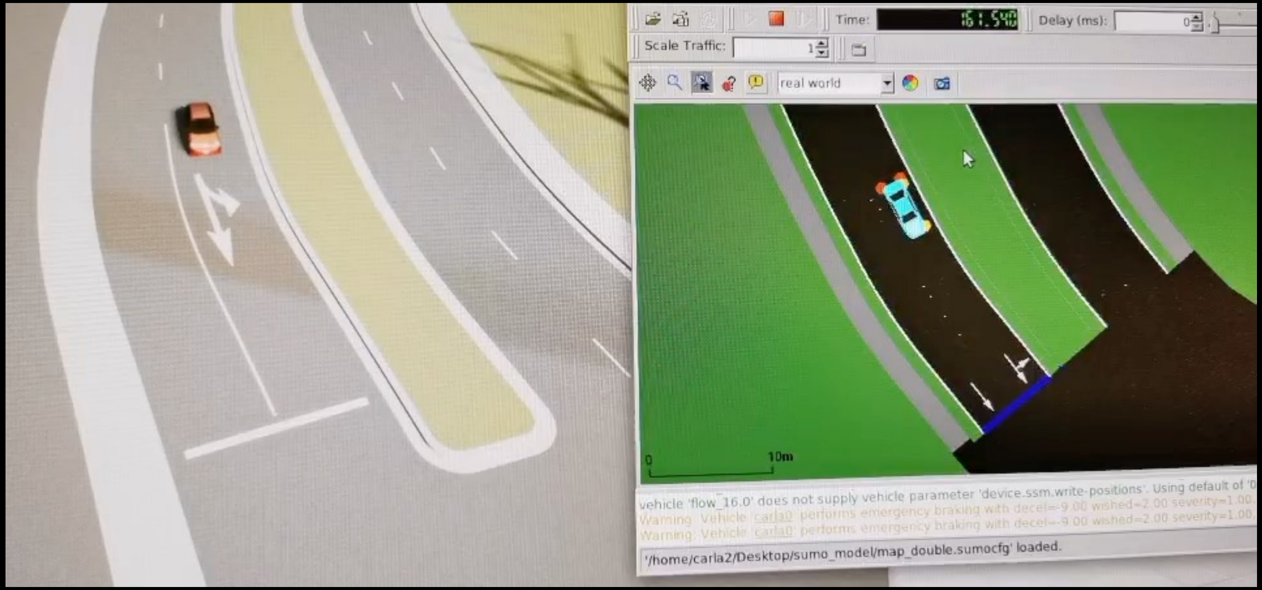
co- simulation



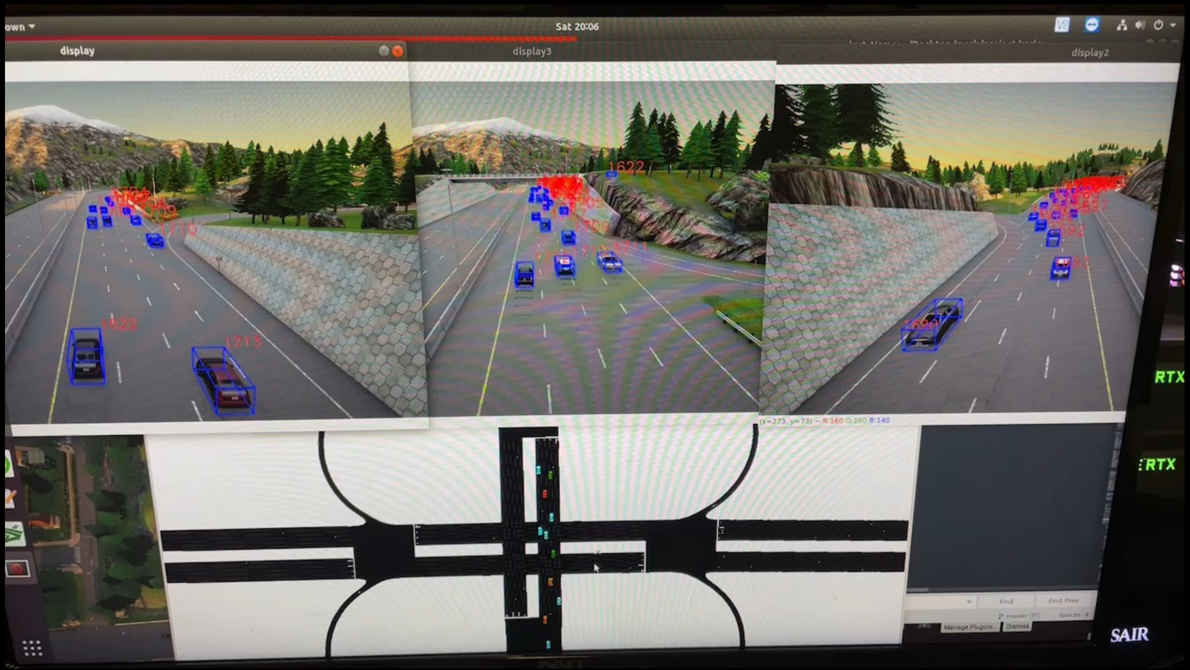
Sumo co-simulation

Unity-Sumo co-simulation

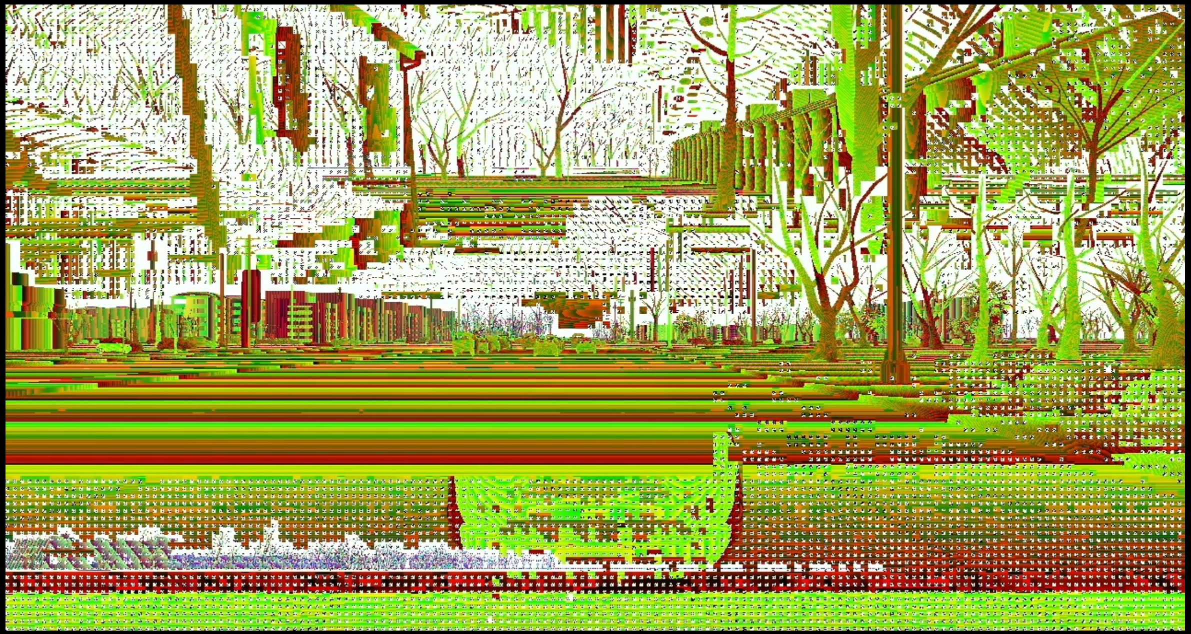
Carla-Sumo co-simulation



Co-simulation for Traffic Flow



RSU cooperative perception



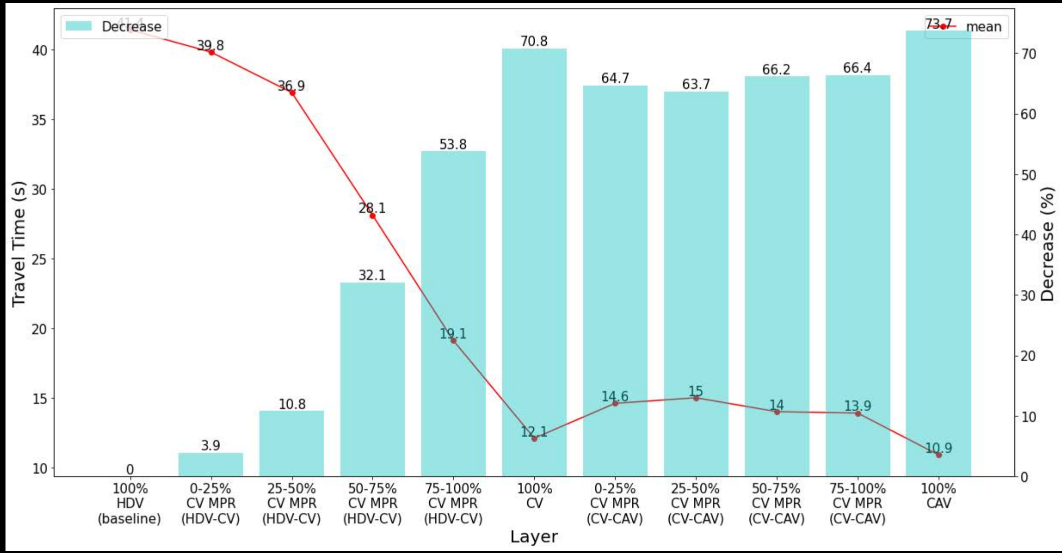
Camera Depth (Raw)

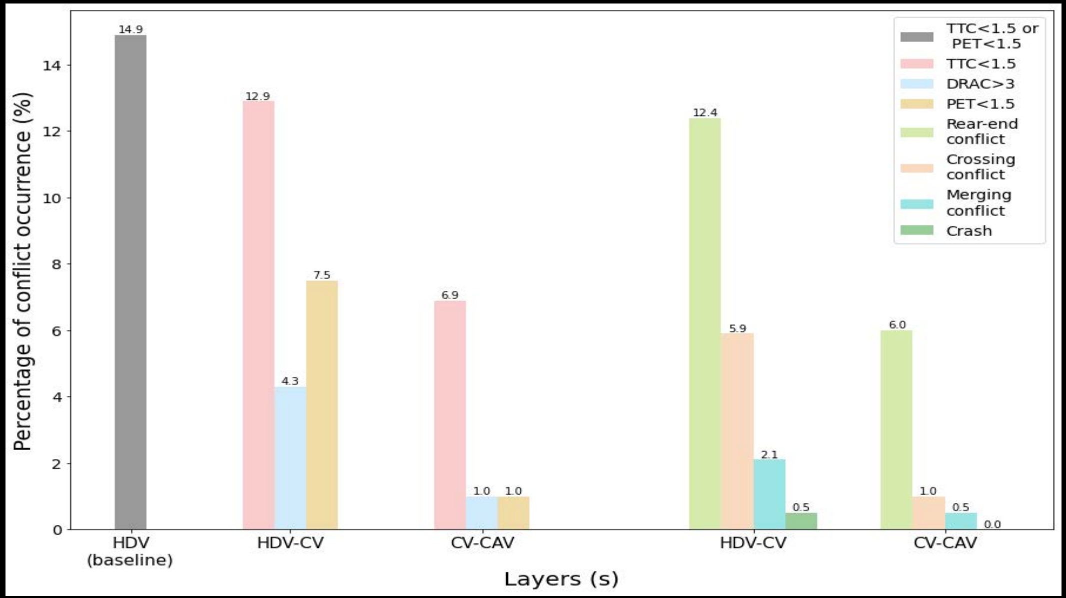
Carla sensor demo

- CAV, sensor simulation by Carla
- Traffic generated by Sumo
- CAV-HDV mixed environment

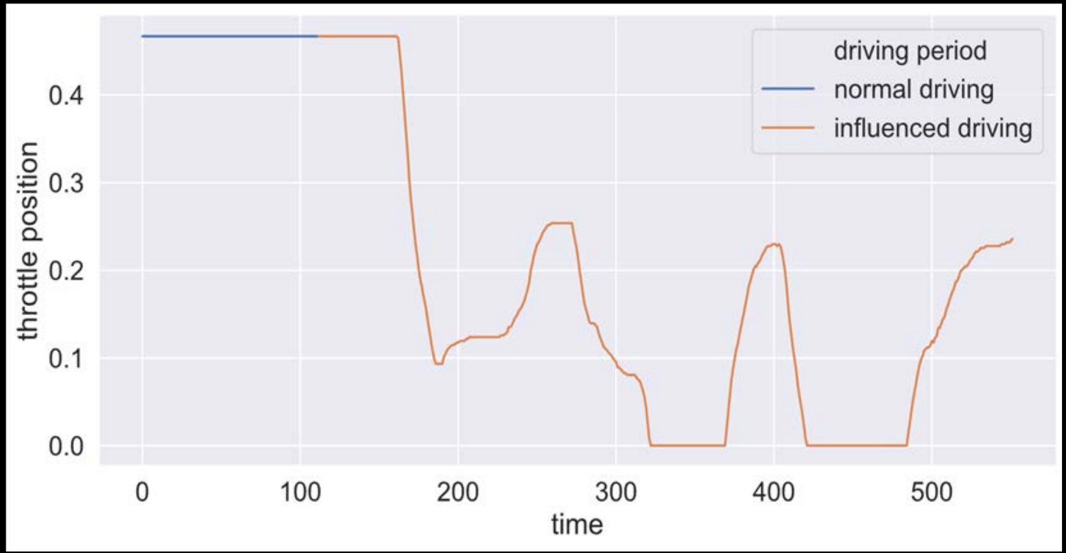
Simulation output

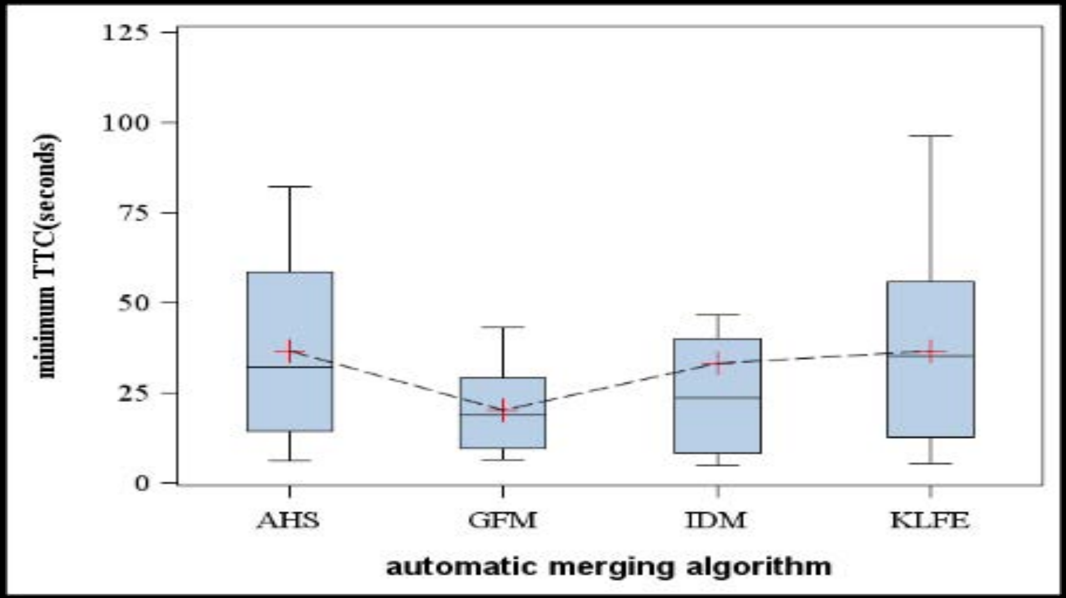
Cooperative driving at intersection



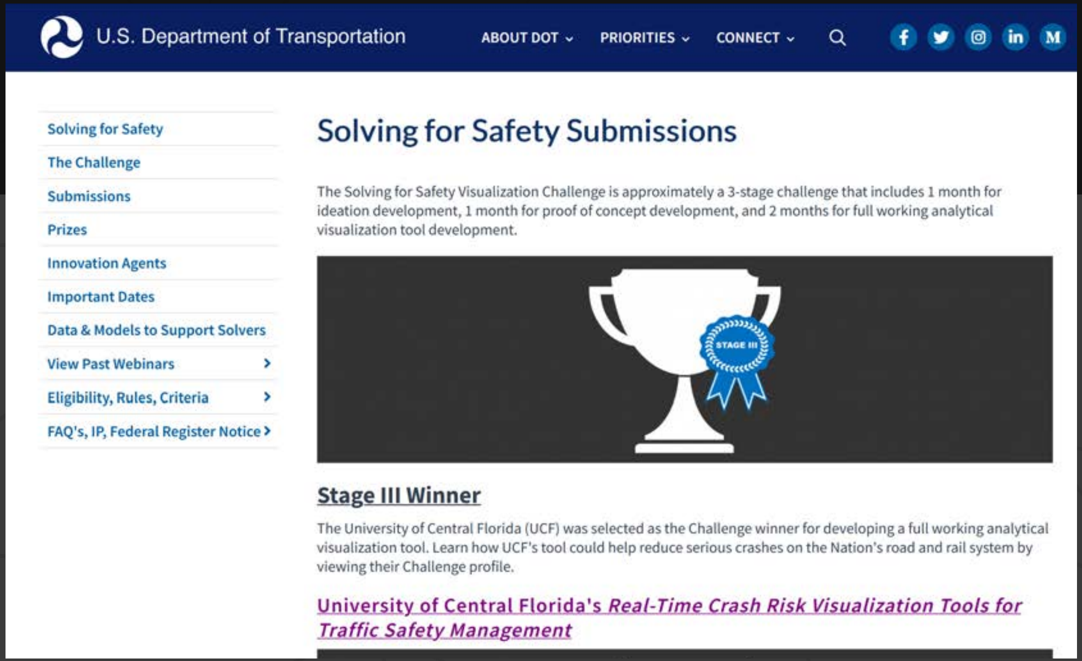


CAV ramp merging





Safety Data Initiative (SDI) tool


U.S. Department of Transportation
ABOUT DOT PRIORITIES CONNECT

- Solving for Safety
- The Challenge
- Submissions
- Prizes
- Innovation Agents
- Important Dates
- Data & Models to Support Solvers
- View Past Webinars
- Eligibility, Rules, Criteria
- FAQ's, IP, Federal Register Notice

Solving for Safety Submissions

The Solving for Safety Visualization Challenge is approximately a 3-stage challenge that includes 1 month for ideation development, 1 month for proof of concept development, and 2 months for full working analytical visualization tool development.

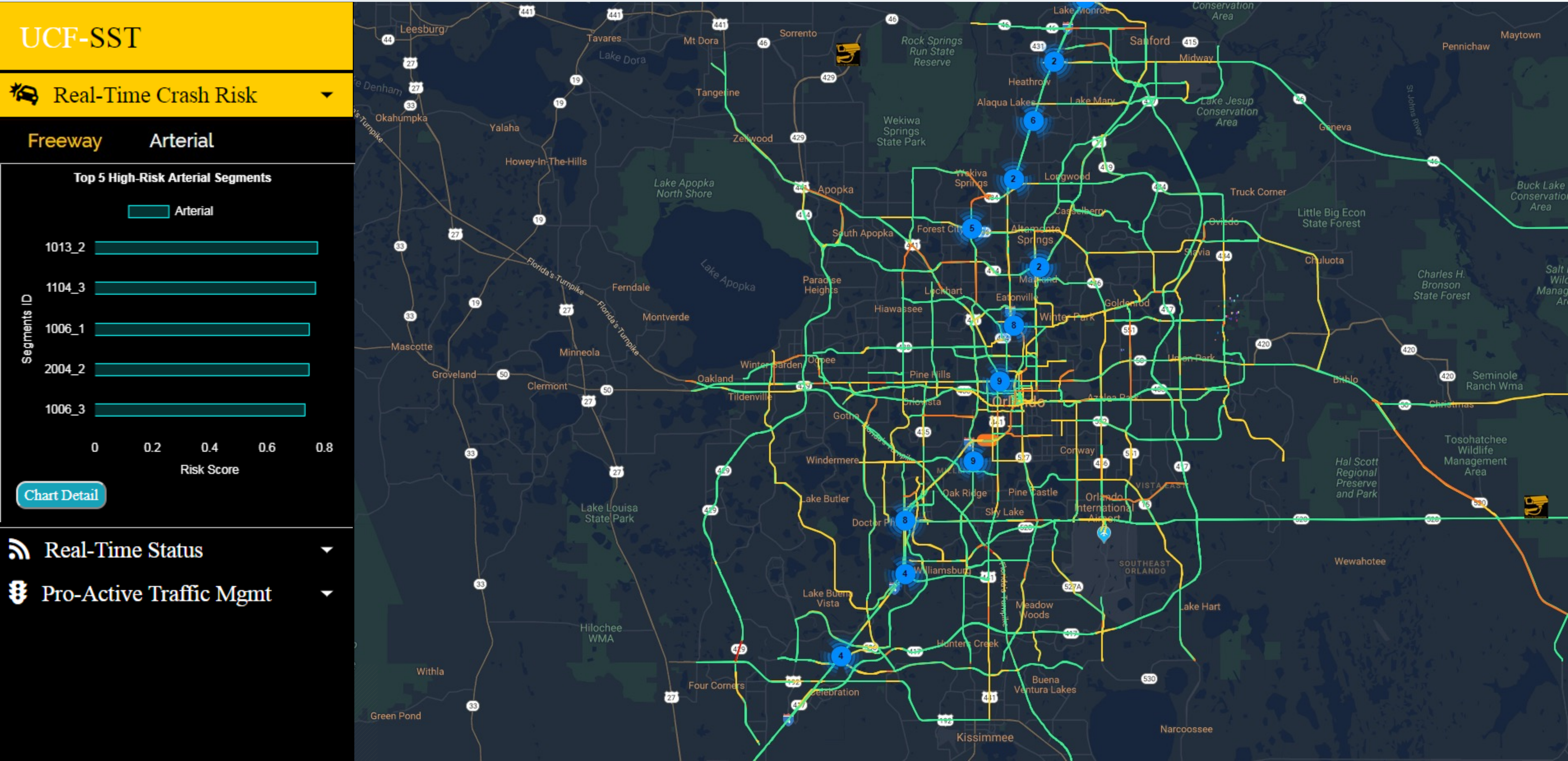
STAGE III

Stage III Winner

The University of Central Florida (UCF) was selected as the Challenge winner for developing a full working analytical visualization tool. Learn how UCF's tool could help reduce serious crashes on the Nation's road and rail system by viewing their Challenge profile.

University of Central Florida's *Real-Time Crash Risk Visualization Tools for Traffic Safety Management*

REAL-TIME CRASH RISK VISUALIZATION
for Operators



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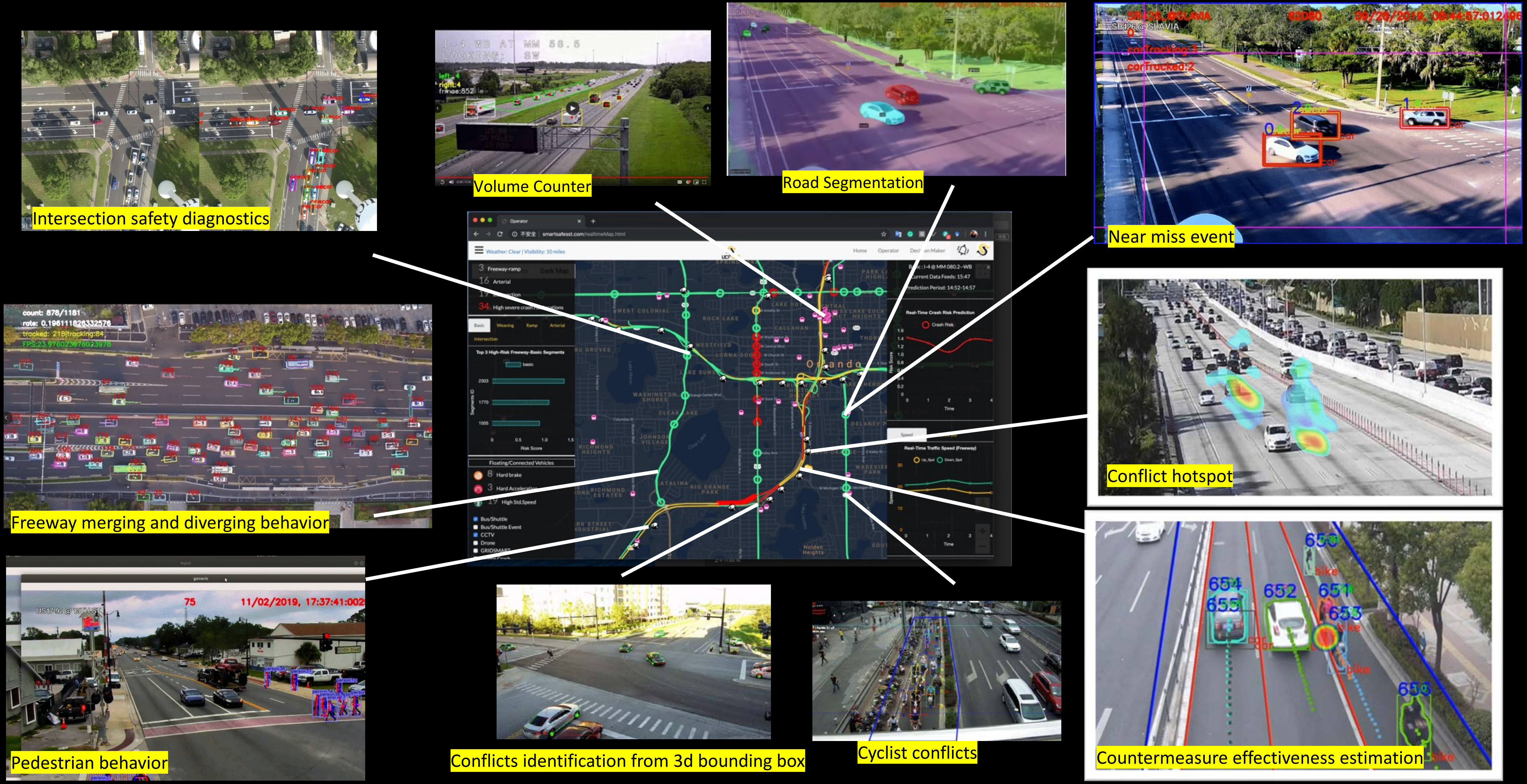
Intersection safety diagnostics
Volume Counter
Road Segmentation
Near miss event
Freeway merging and diverging behavior
Conflict hotspot
Pedestrian behavior
Conflicts identification from 3d bounding box
Cyclist conflicts
Countermeasure effectiveness estimation

Vision for Transportation Safety

- **More Proactive (but data intensive) approaches / Real-Time**
- **Multi-driver-in-the-loop Co-simulation**
- **Ever richer information**
    - Smartphones, sensors, cameras, onboard vehicle hardware, provide continuous data
    - Traffic status, weather conditions in real-time
- **Better operation and safety**
    - Bottleneck detection in real-time
    - Crash risk evaluation and prediction in real-time
- **More accurate prediction**
    - Formation of congestion, queue length, congestion duration
    - Crash-prone conditions: unstable traffic flow, adverse weather
- **Timely communication**
    - Connected Vehicles
    - Media: smartphone, DMS, radio
    - Suggested countermeasures: trip planning, route choice, travel time calculation, VSL, speed advice, etc.
- **Smart Cities' research**
    - FUTURe CITy Initiative: Fostering Smart Urban Transformation and Ubiquitous Resilience with Connected Infrastructure and Technology

THANK YOU

Mohamed Abdel-Aty and UCF SST team