MATLAB EXPO

5月28日, 2024 | 北京

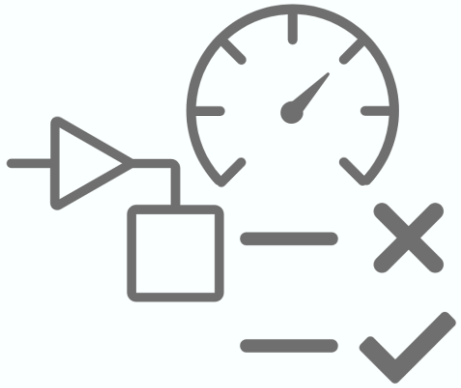
使用MATLAB, Simulink 和RoadRunner仿真自动驾驶

马秀丹, MathWorks中国

MathWorks

Industry continues to invest in virtual scenes and scenarios

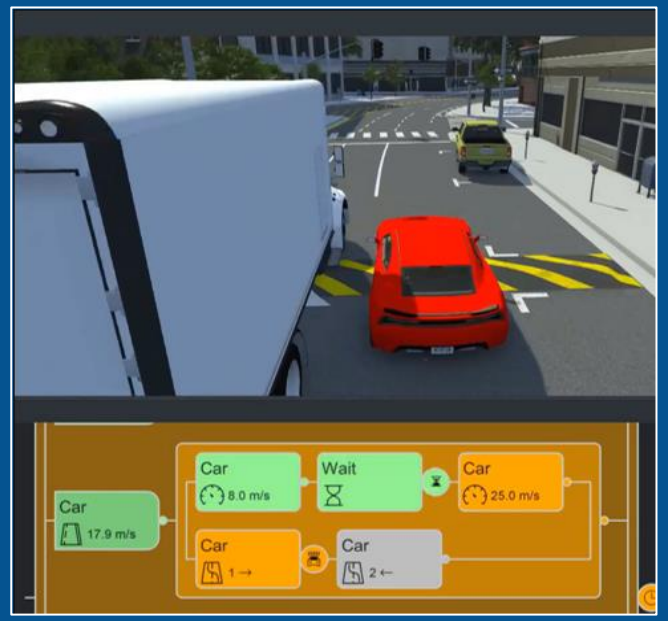
Promote interoperability across simulation tools with ASAM standards



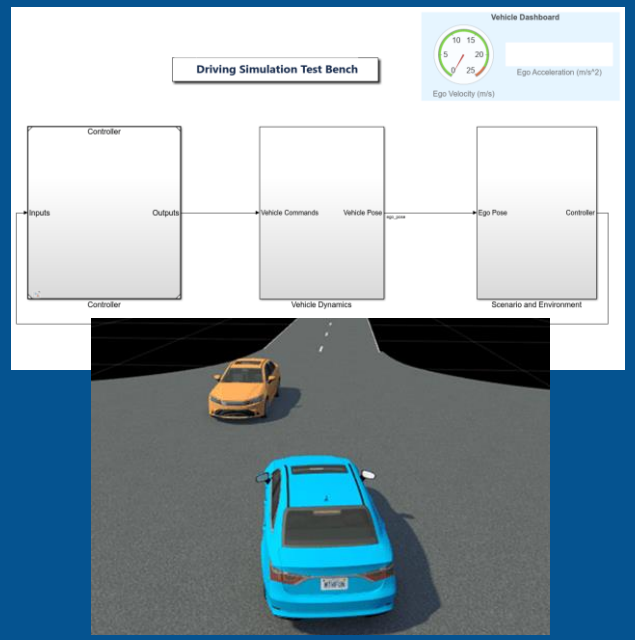
Enable early design and verification with closed-loop simulation

Increase confidence by reproducing real-world scenarios

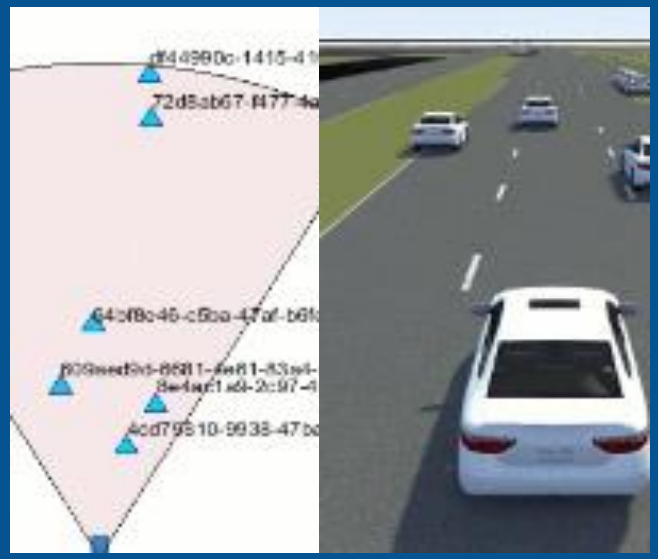
Develop automated driving scenarios with MATLAB, Simulink, and RoadRunner



Design scenes & scenarios for common driving simulation tools

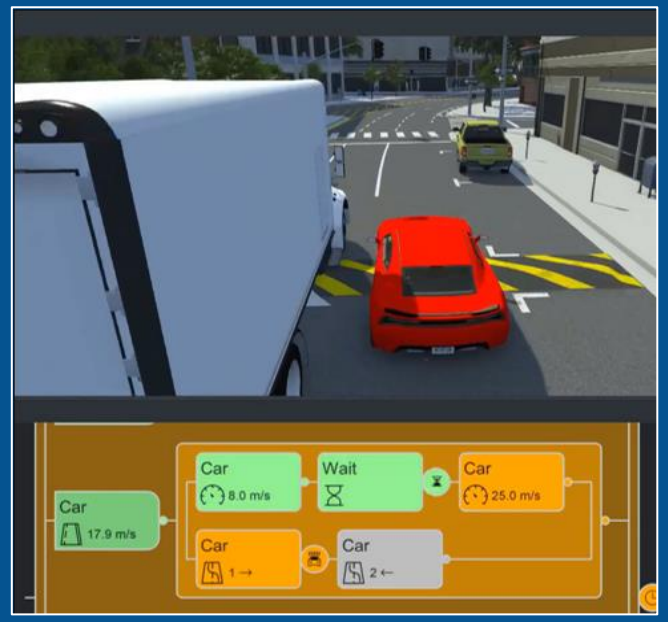


Simulate driving applications for early design and test

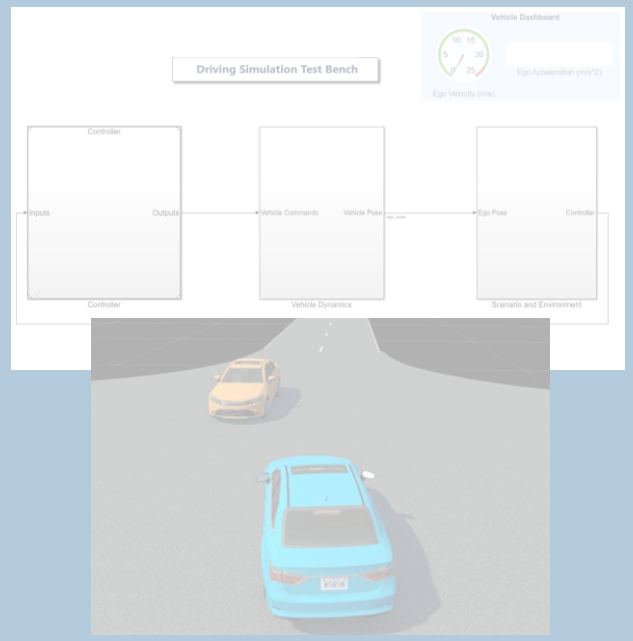


Build scenarios from maps and recorded sensor data

Develop automated driving scenarios with MATLAB, Simulink, and RoadRunner



Design scenes & scenarios for common driving simulation tools



Simulate driving applications for early design and test

Build scenarios from maps and recorded sensor data

Design 3D scenes for automated driving applications with RoadRunner

Here HD Live Map
TomTom HD Maps
Apollo HD Maps
Custom HD Maps

OpenDRIVE
OpenStreetMap
OpenCRG
Zenrin SD Maps

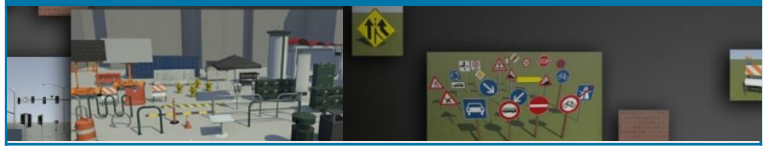
Geographic Information System (GIS) Files
- Point clouds
- Orthoimagery
- Vector data
- Elevation data

Custom Assets

RoadRunner Scene Builder

RoadRunner

RoadRunner Asset Library



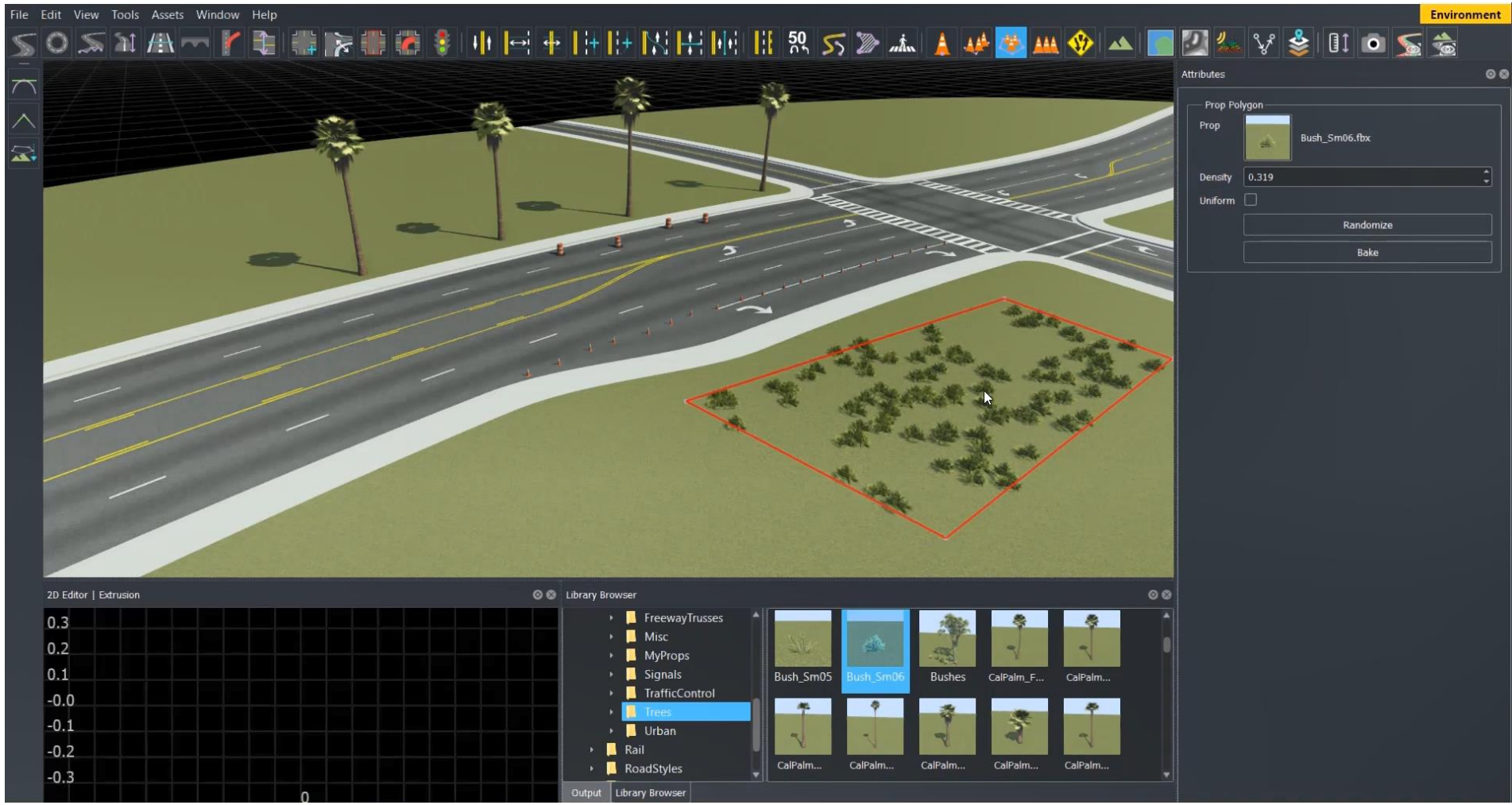
OpenDRIVE

Filmbox

Third Party Simulators
- CARLA
- Unreal Engine®
- Unity®
- LGSVL
- VIRES Virtual Test Drive
- rFpro
- IPG Carmaker
- Cognata
- Baidu Apollo
- Tesis Dynaware
- Simcenter Prescan
- NVIDIA DRIVE Sim through Universal Scene Description (USD)

Interactively design scenes with RoadRunner

- Author realistic roads and intersections
- Import/export OpenDRIVE
- Import HD maps
- Import Geographic Information System (GIS) files
- Export to common driving simulation environments



RoadRunner, RoadRunner Asset Library, RoadRunner Scene Builder

Chinese traffic signs assets library

《道路交通标志和标线 第2部分:道路交通标志》（GB 5768.2—2022）

Develop scenarios for automated driving applications with RoadRunner Scenario

Trajectories
- CSV
- OpenSCENARIO 1.x

Automate Tasks
(import, export, set variables,…)

- MATLAB*
- C/C++
- Python
- Any gRPC supported language

RoadRunner Scenario

RoadRunner

Trajectories and logic
- OpenSCENARIO 1.x
- OpenSCENARIO 2.0

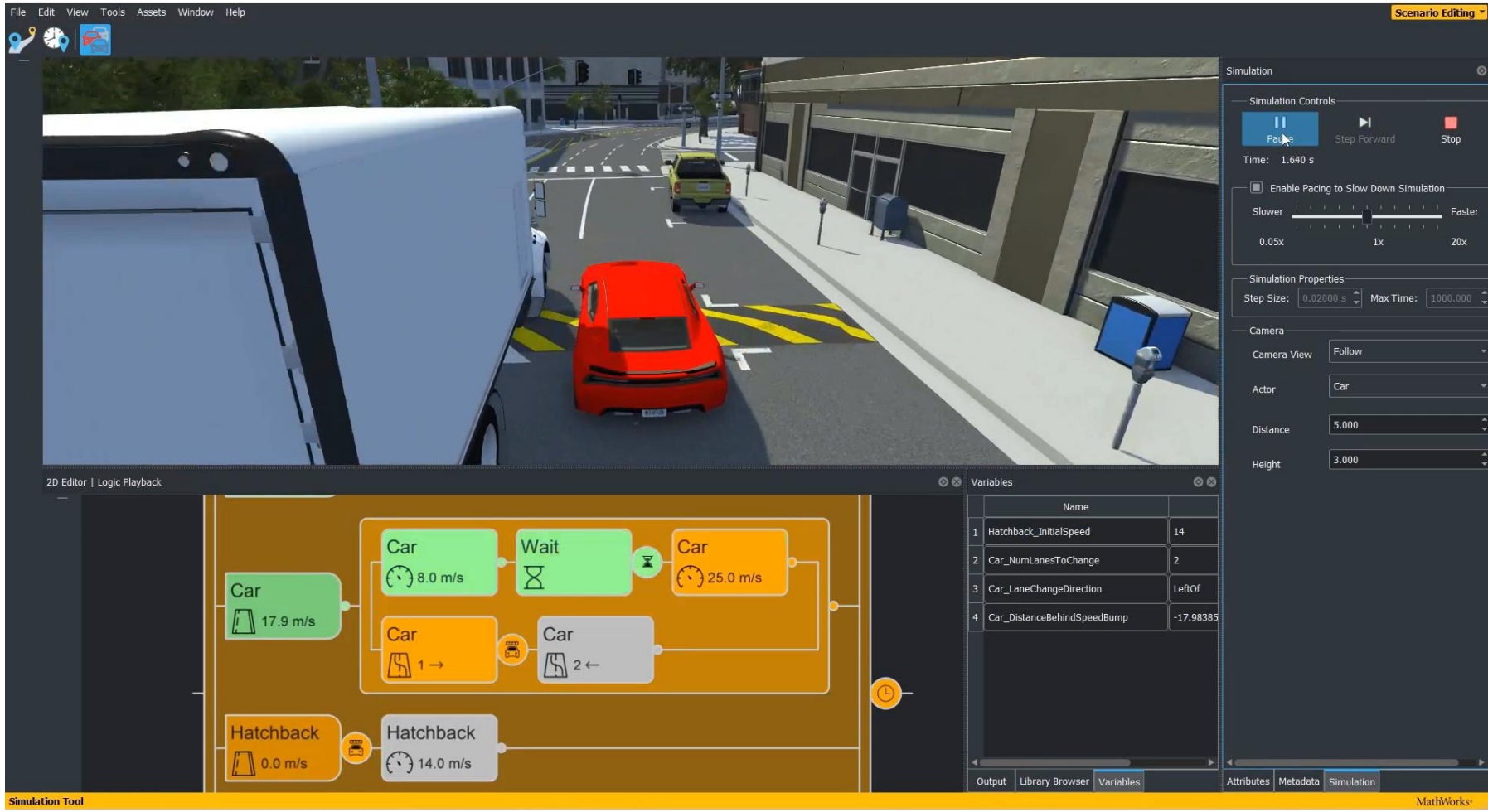
Simulate Actor Behaviors

- MATLAB*
- Simulink*
- CARLA

* = Enabled through Automated Driving Toolbox

Interactively design scenarios with RoadRunner Scenario

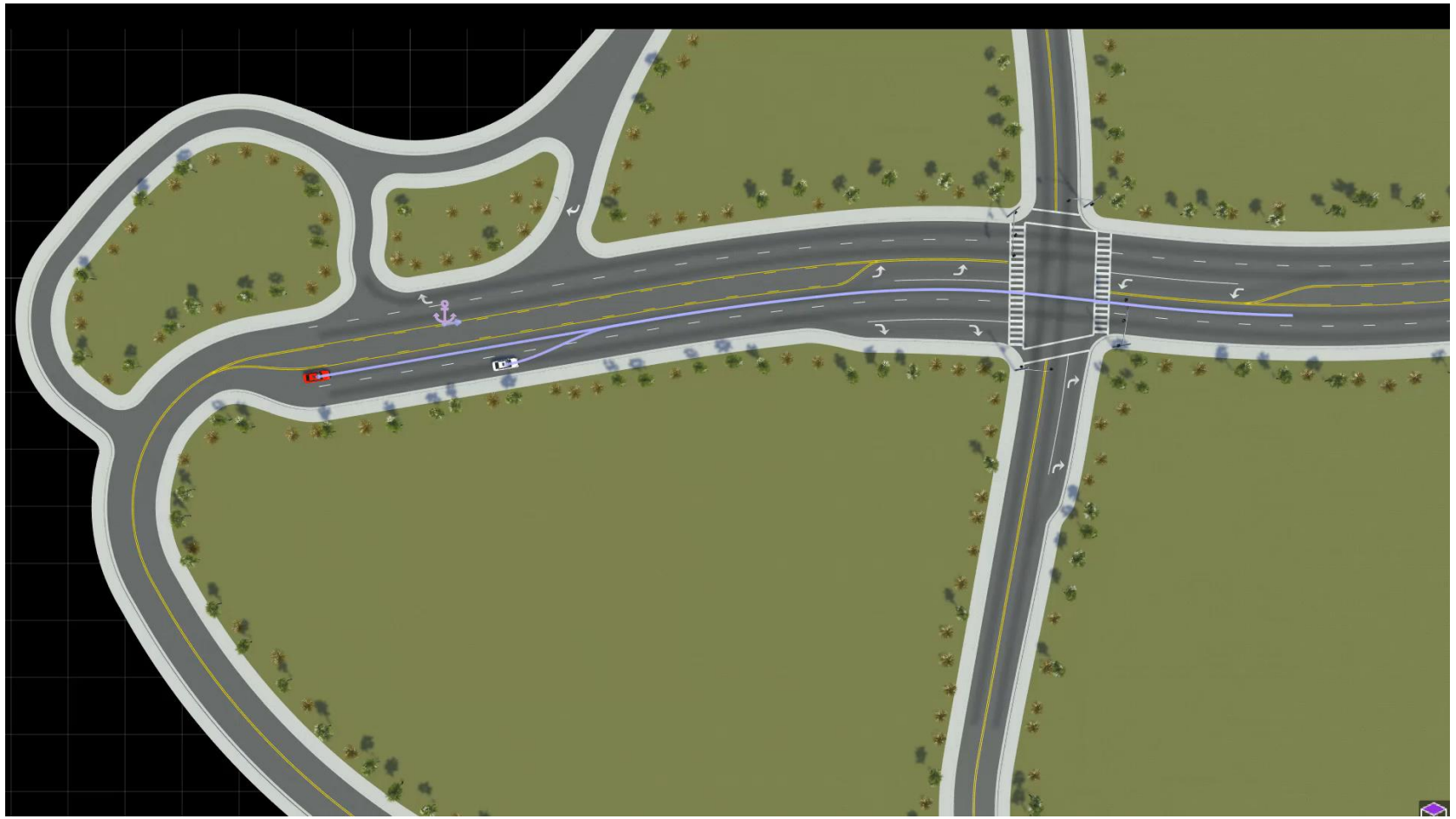
- Add various vehicles and pedestrians
- Author trajectories
- Specify actions and logic
- Parameterize variations



[Scenario Edit Tool](#)

RoadRunner Scenario

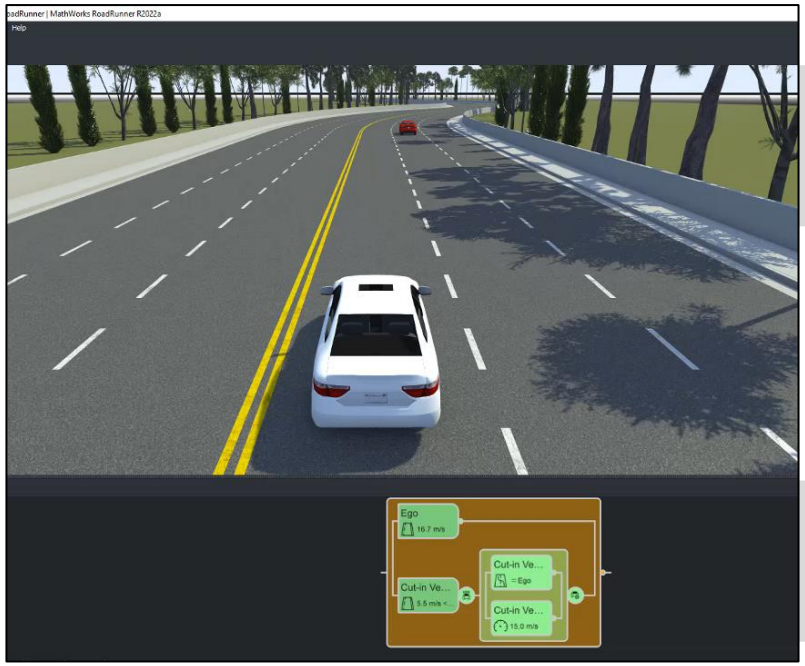
Relocate scenarios to different scenes



[Remap Anchors In A Scenario Example](#)

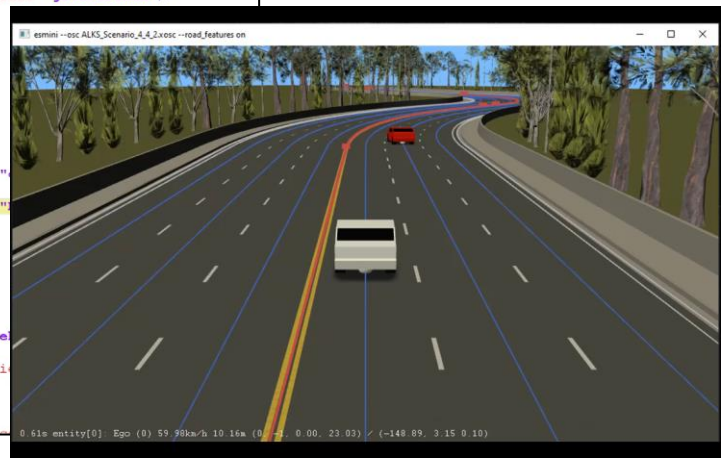
RoadRunner Scenario

Export scenarios to OpenSCENARIO



OpenSCENARIO V1.x XML

```
<Condition name="Start Condition of Event_Vehicle2" conditionEdge="none">
    <ByValueCondition>
        <SimulationTimeCondition value="0" rule="greaterThan"/>
    </ByValueCondition>
</Condition>
</ConditionGroup>
</StartTrigger>
</Event>
<Event name="Event_Vehicle2_2" priority="overwrite">
<Action name="Speed_Action_Vehicle2_2">
<PrivateAction>
<LongitudinalAction>
<SpeedAction>
<SpeedActionDynamics dynamicsShape="
<SpeedActionTarget>
<RelativeTargetSpeed entityRef="
</SpeedActionTarget>
</SpeedAction>
</LongitudinalAction>
</PrivateAction>
</Action>
<StartTrigger>
<ConditionGroup>
<Condition name="Start Condition of Event_Ve
<ByEntityCondition>
<TriggeringEntities triggeringEntiti
<EntityRef entityRef="Ego"/>
</TriggeringEntities>
<EntityCondition>
```



https://github.com/esmini/esmini

OpenSCENARIO V2.0 DSL

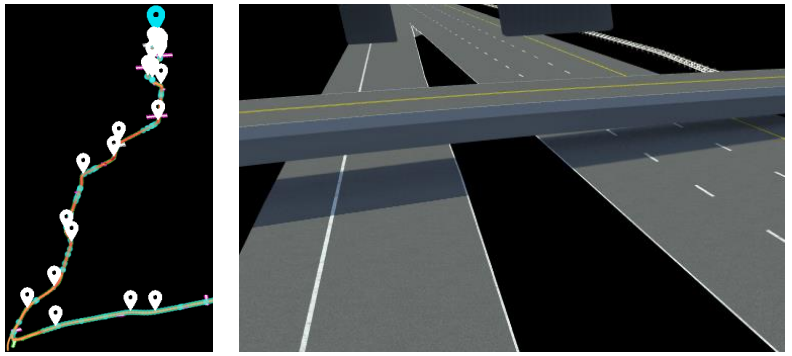
```
81      do parallel:
82          ego.drive() with:
83              along(sedan__route)
84              speed(16.66mps, at: start)
85          serial:
86              cut-in__vehicle.drive() with:
87                  along(sedan2__route)
88                  speed(5.5mps, slower_than: ego
89                  until (cut-in__vehicle.object_
90              parallel:
91                  cut-in__vehicle.change_lane(si
92                  cut-in__vehicle.drive() with:
93                      speed(15mps, at: end, shap
94              with:
95                  until (ego.time_to_collision(c
96
```

[Export to ASAM OpenSCENARIO](#)

RoadRunner Scenario

Learn about new features to design scenes and scenarios

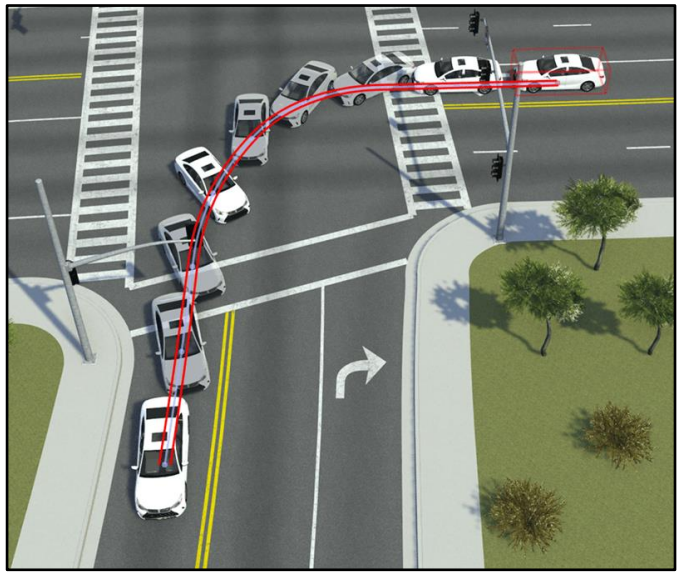
Specify Routes to Import HERE HD Live Map



[Specify Route to Import HERE HD Live Map Data and Build Scenes]
RoadRunner Scene Builder

R2023b

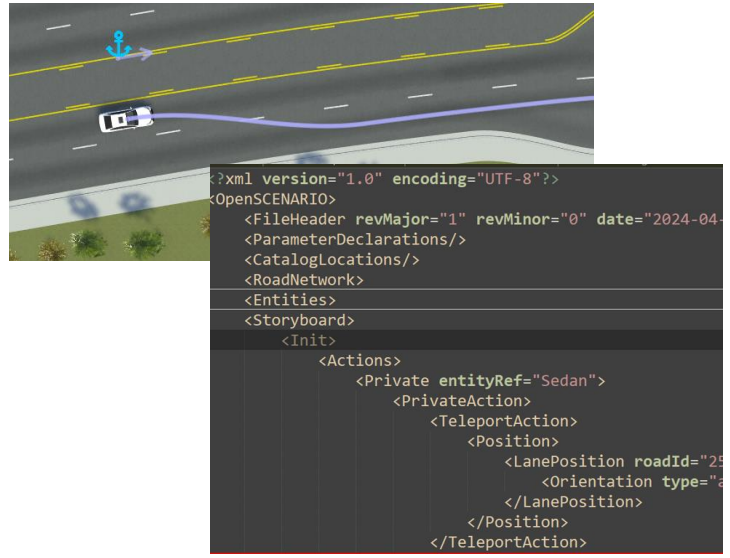
Define Actor Orientation



[Actor Orientation Tool]
RoadRunner Scenario

R2024a

OpenSCENARIO Export Enhancements

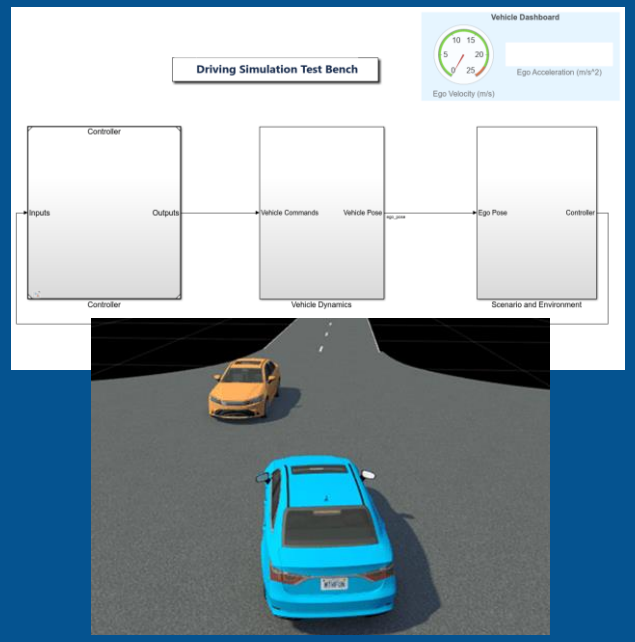


[Specify the export options for non-instantaneous actions]
RoadRunner Scenario

R2023b

Develop Automated Driving Scenarios with MATLAB, Simulink, and RoadRunner

Design scenes & scenarios for common driving simulation tools



Simulate driving applications for early design and test

Build scenarios from maps and recorded sensor data

Simulate scenes and scenarios for driving applications

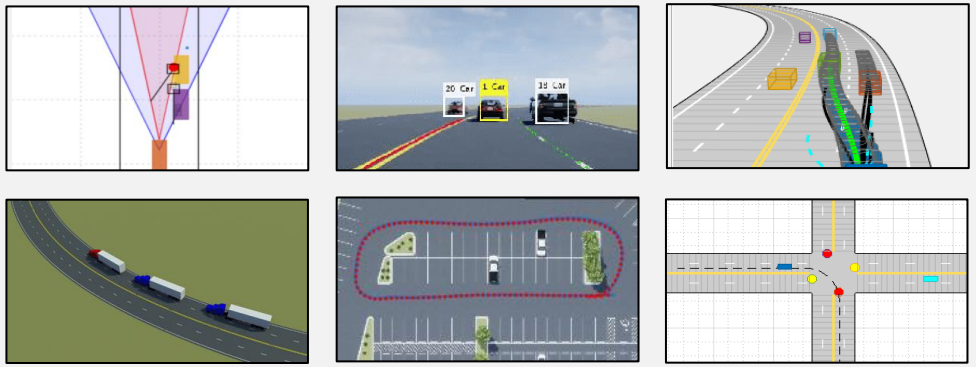
RoadRunner

RoadRunner Scenario

Vehicle Dynamics Blockset

Automated Driving Toolbox

Application Examples



Simulink Test

Simulink Requirements

Simulink Real-Time

Embedded Coder

GPU Coder

Lidar Toolbox

Computer Vision Toolbox

Navigation Toolbox

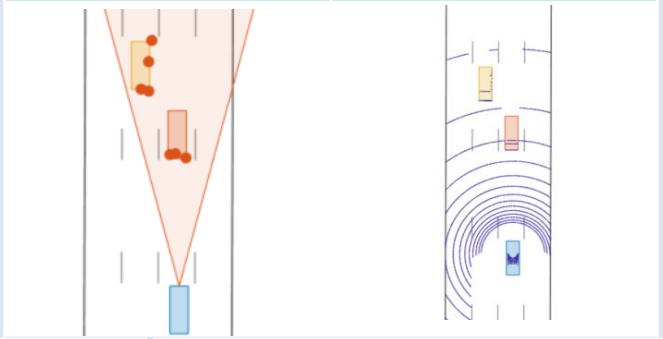
Sensor Fusion & Tracking Toolbox

MPC Toolbox

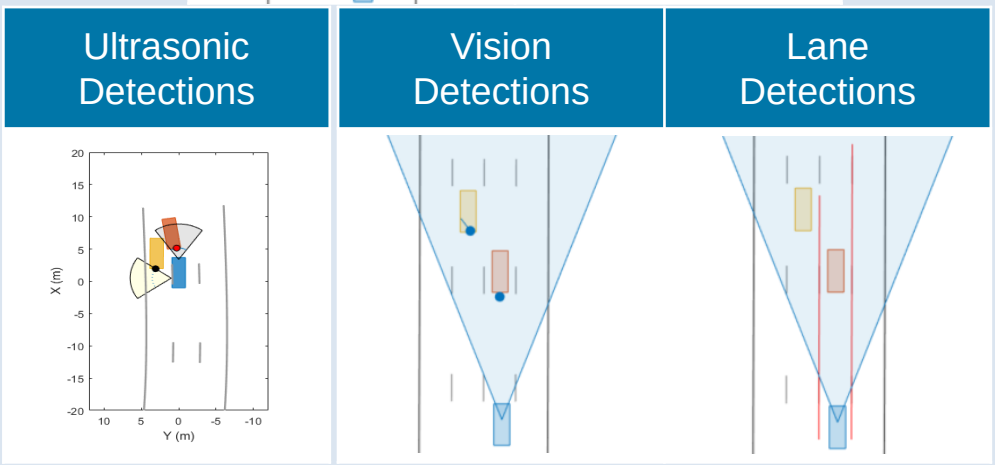
Simulate sensors for automated driving applications

Automated Driving Toolbox (ADT)

- Radar Detections
- Lidar



- Ultrasonic Detections
- Vision Detections
- Lane Detections



ADT + Unreal Engine

- Monocular Camera
- Semantic Segmentation

- Depth
- Fisheye Camera

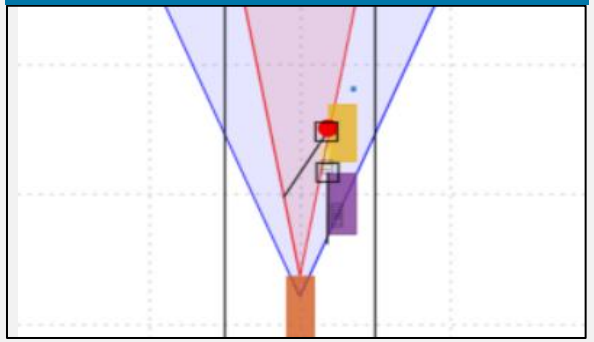
Navigation Toolbox

- Wheel Encoder
- Global Positioning System (GPS)
- Inertial Measurement Unit (IMU)
- Inertial Navigation System (INS)

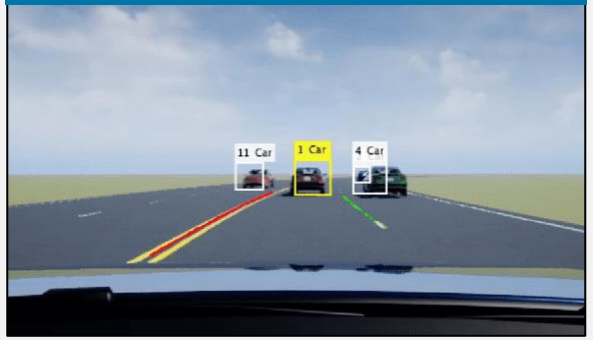
Use application example families as a basis for design and testing

Application Examples

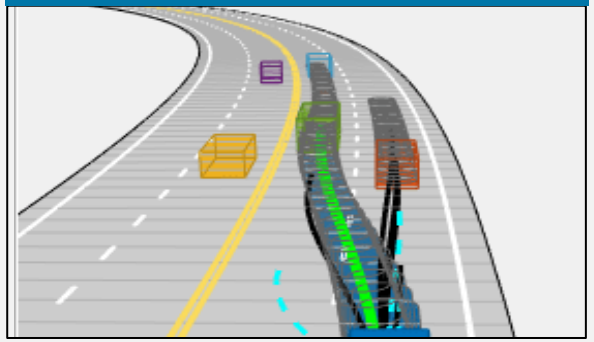
Emergency Braking



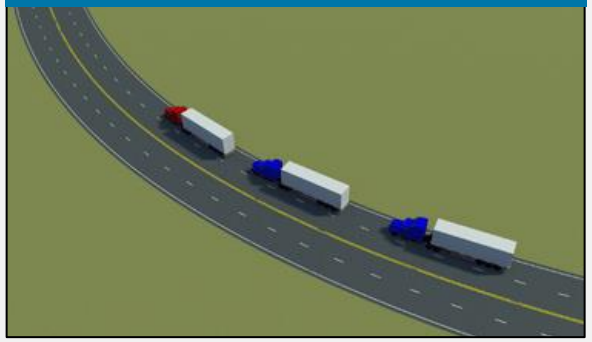
Lane Following



Lane Change

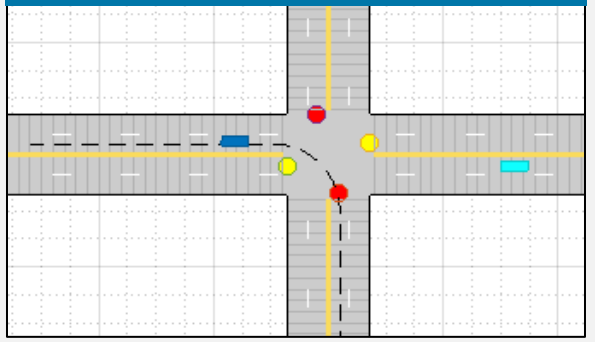


Platooning



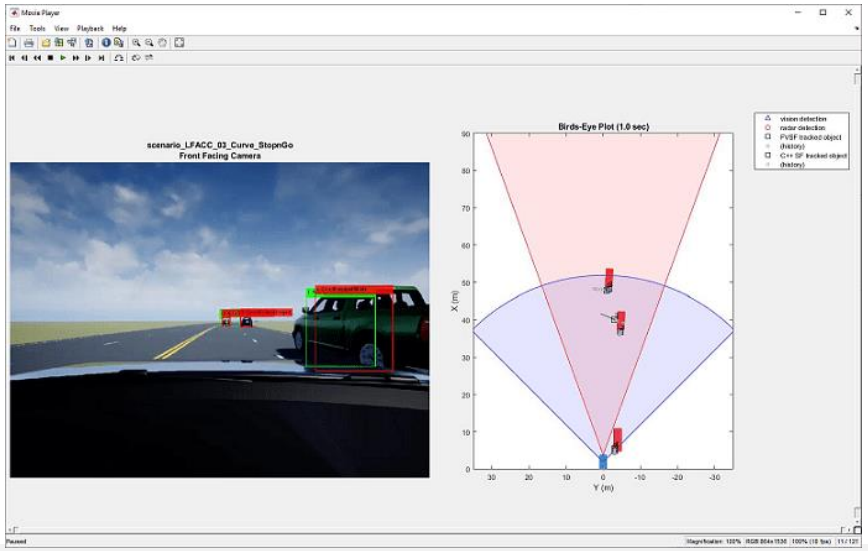
Automated Parking

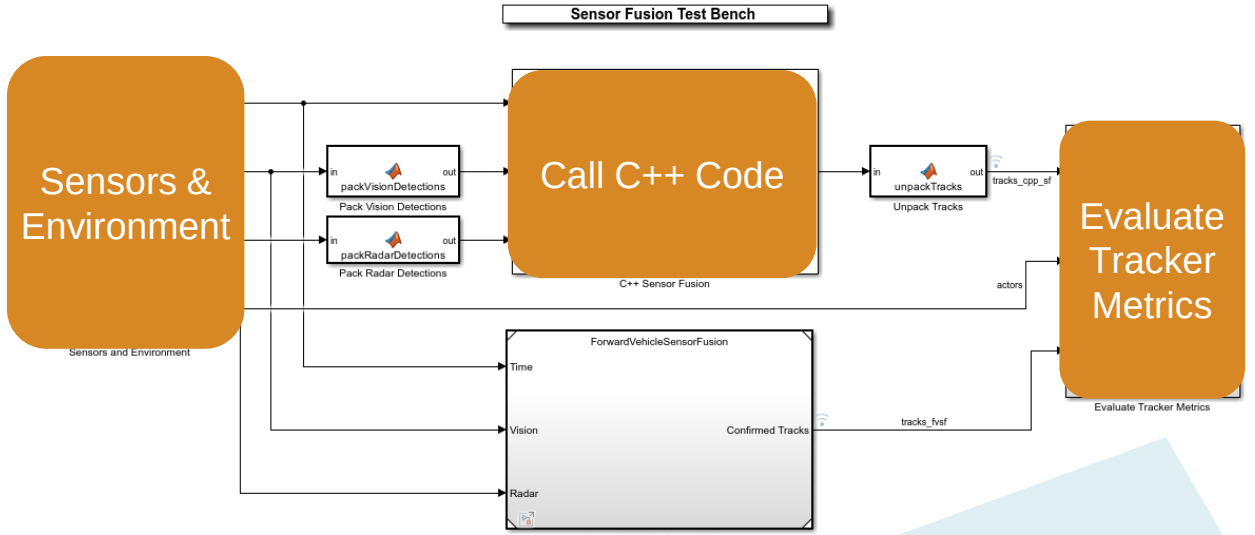
Intersection Negotiation

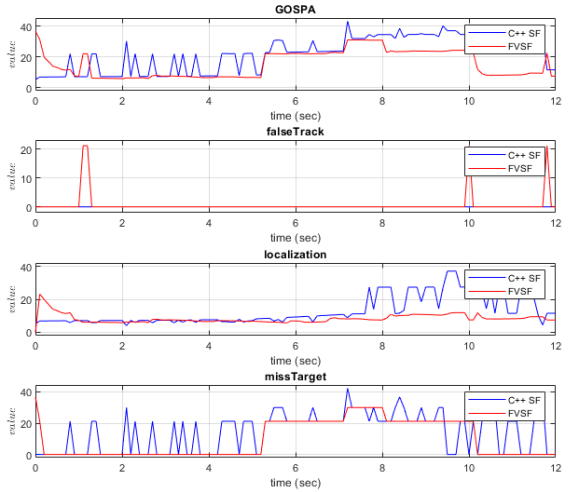


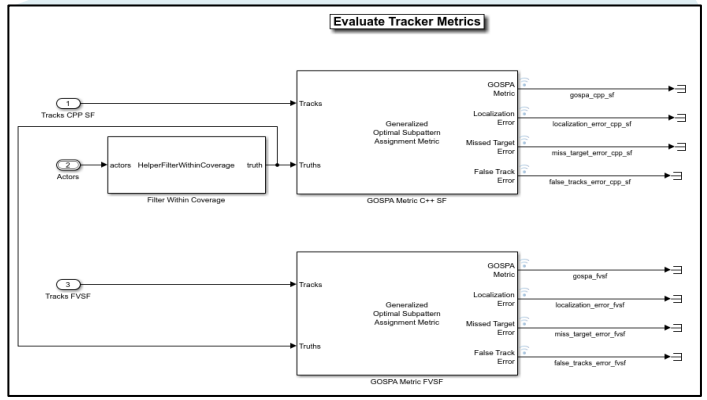
Verify C++ sensor fusion algorithm in Simulink

- Compare the results of C++ code implementation with a reference model using the GOSPA metric
- Visualize simulation in 3D and a bird's-eye plot
- Test the system in other scenarios under additional conditions







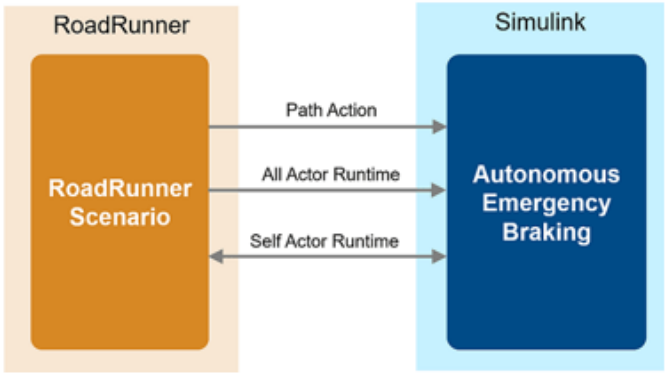


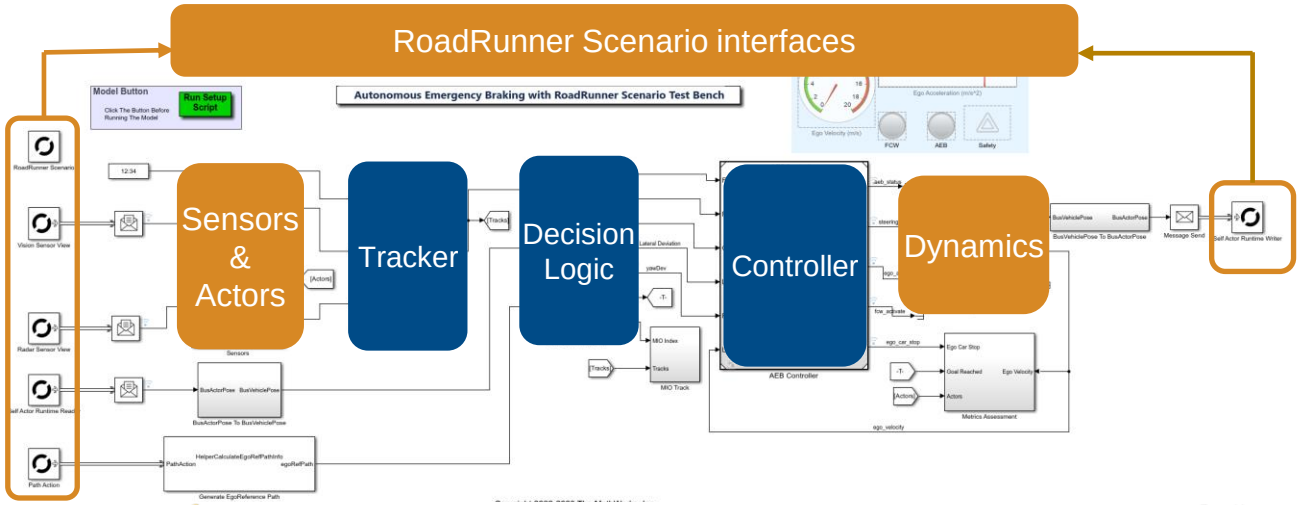
[Integrate and Verify C++ Code of Sensor Fusion Algorithm in Simulink]

Automated Driving Toolbox, Simulink, Sensor Fusion and Tracking Toolbox

R2023b

Automate testing of scenario variants using Simulink Test





- Simulate Simulink with RoadRunner Scenario
- Test Euro NCAP Car-to-Car Front turn-across-path (CCFtap)
- Create and run variants with Simulink Test

[Autonomous Emergency Braking with RoadRunner Scenario]

Automated Driving Toolbox, RoadRunner Scenario, Simulink, Simulink Test

R2023b

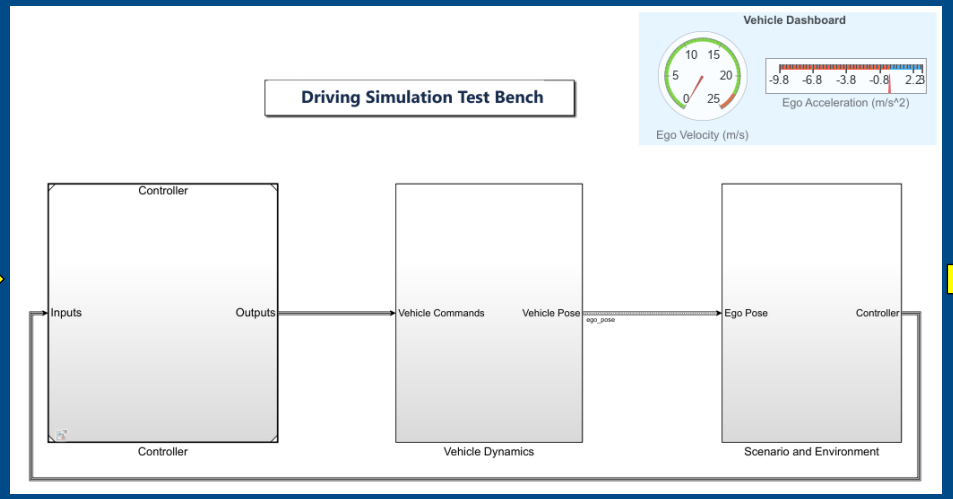
Automate testing for AEB Euro NCAP scenarios

Test Suite for Euro NCAP® Protocols

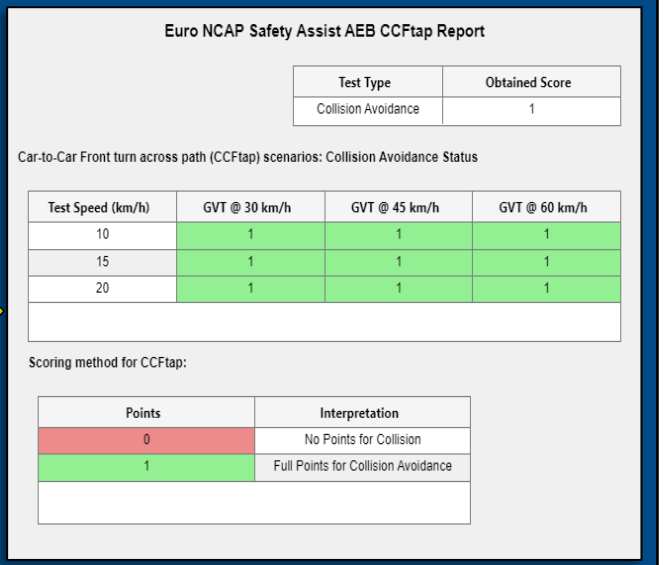
AEB Euro NCAP Scenarios

- Car-To-Car Rear Stationary
- Car-To-Car Rear Moving
- Car-To-Car Rear Braking
- Car-to-Car Front Turn-Across-Path
- Car-to-Car Crossing Straight Crossing Path
- Car-to-Car Front Head-On Straight
- Car-to-Car Front Head-On Lane change

AEB Test Bench



Euro NCAP Report



Euro NCAP Safety Assist AEB CCFtap Report

Test Type	Obtained Score
Collision Avoidance	1

Car-to-Car Front turn across path (CCFtap) scenarios: Collision Avoidance Status

Test Speed (km/h)	GVT @ 30 km/h	GVT @ 45 km/h	GVT @ 60 km/h
10	1	1	1
15	1	1	1
20	1	1	1

Scoring method for CCFtap:

Points	Interpretation
0	No Points for Collision
1	Full Points for Collision Avoidance

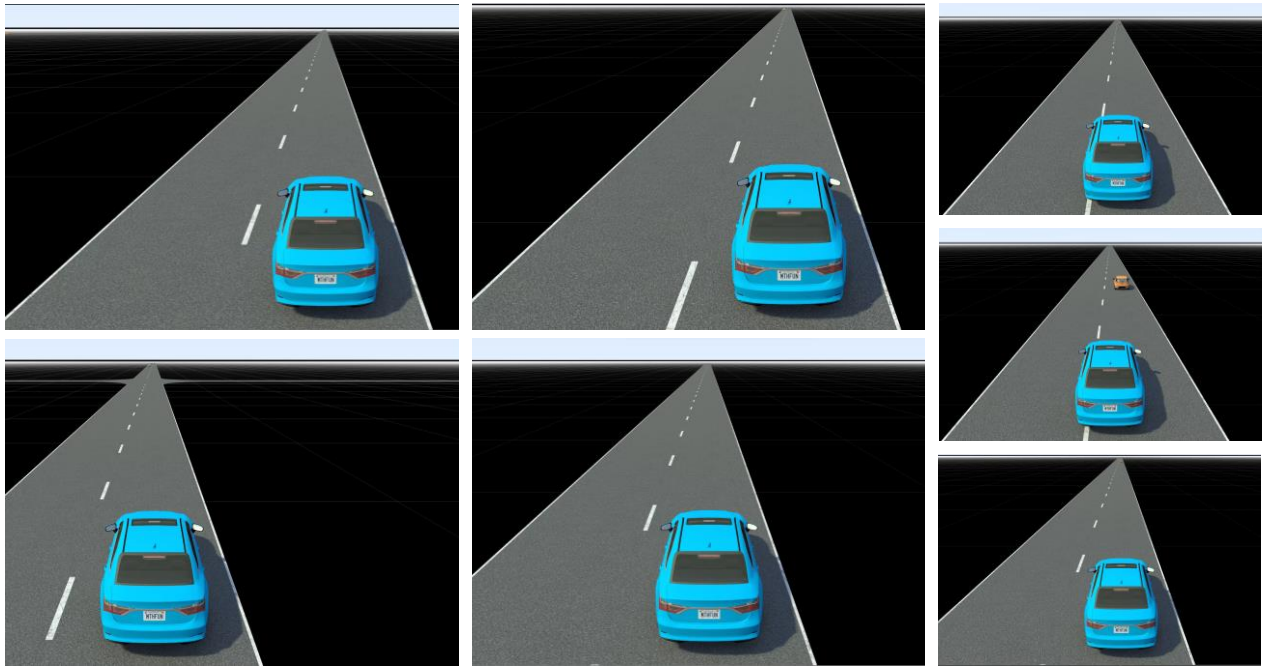
[Get Started with Euro NCAP Test Suite]

Automated Driving Toolbox™ Test Suite for Euro NCAP® Protocols Support Package

R2024a

Automate testing for AEB Euro NCAP scenarios

- **Configure Euro NCAP scenarios**
- Perform iterative testing
- Review Euro NCAP test report
- Replay results from logged data



AEB Car-to-Car

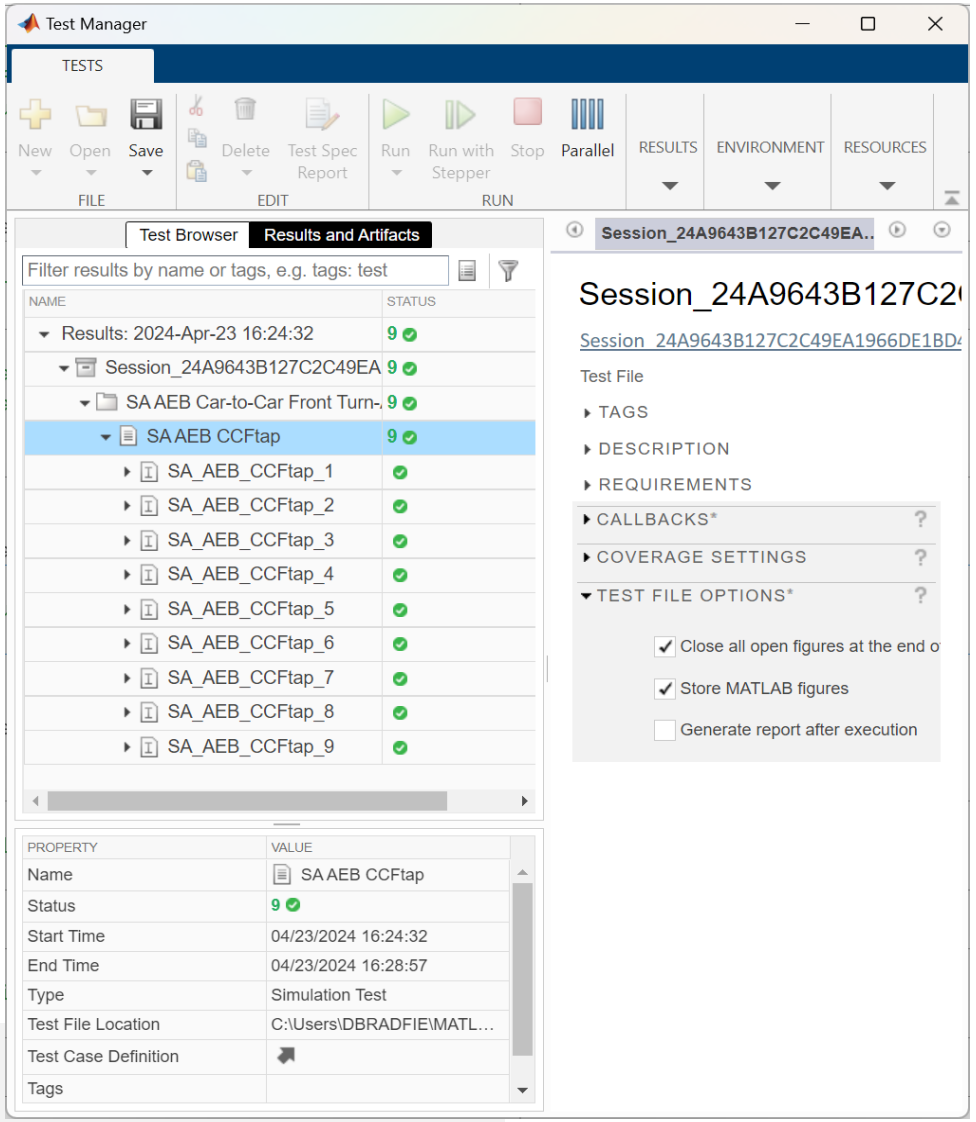
- Rear Stationary
- Rear Moving
- Rear Braking
- Front Turn-Across-Path
- Crossing Straight Crossing Path
- Front Head-On Lane Change
- Front Head-On Straight

[AEB Euro NCAP Testing with RoadRunner Scenario]

Automated Driving Toolbox, RoadRunner Scenario, Simulink Test

Automate testing for AEB Euro NCAP scenarios

- Configure Euro NCAP scenarios
- **Perform iterative testing**
- Review Euro NCAP test report
- Replay results from logged data



[AEB Euro NCAP Testing with RoadRunner Scenario]

Automated Driving Toolbox, RoadRunner Scenario, Simulink Test

Automate testing for AEB Euro NCAP scenarios

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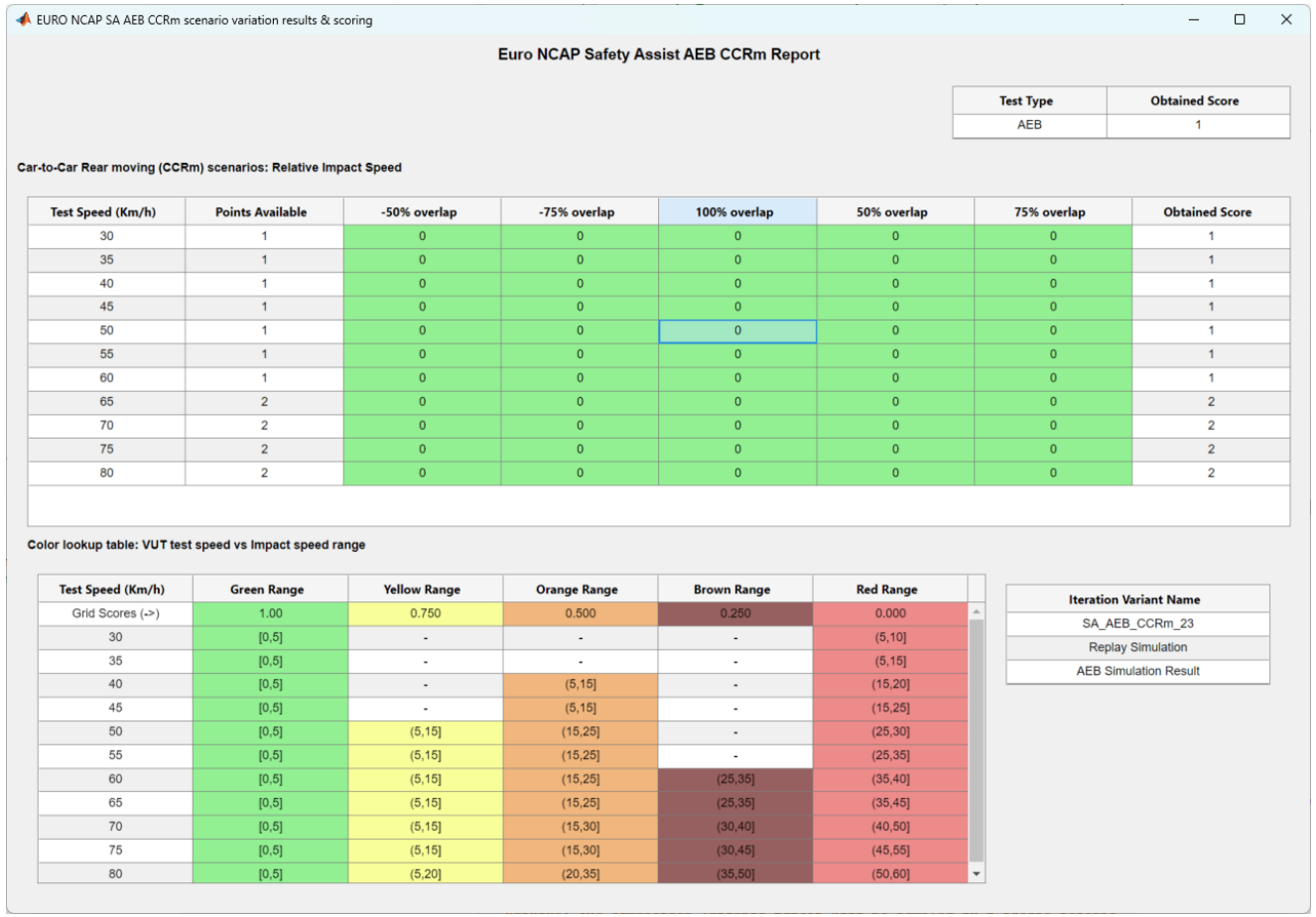
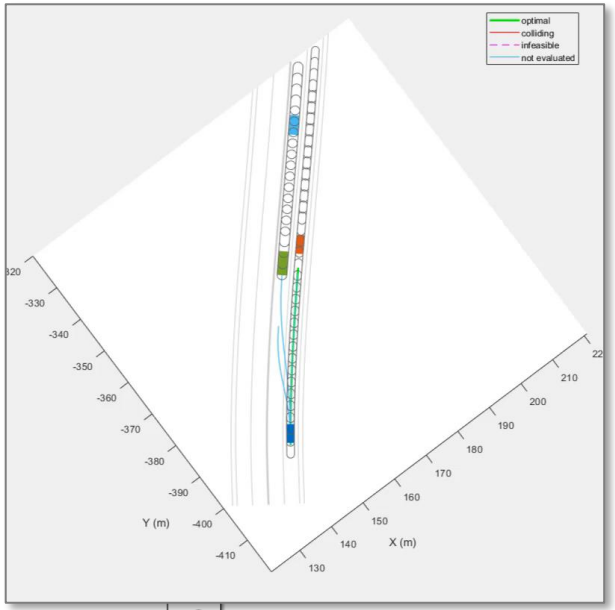


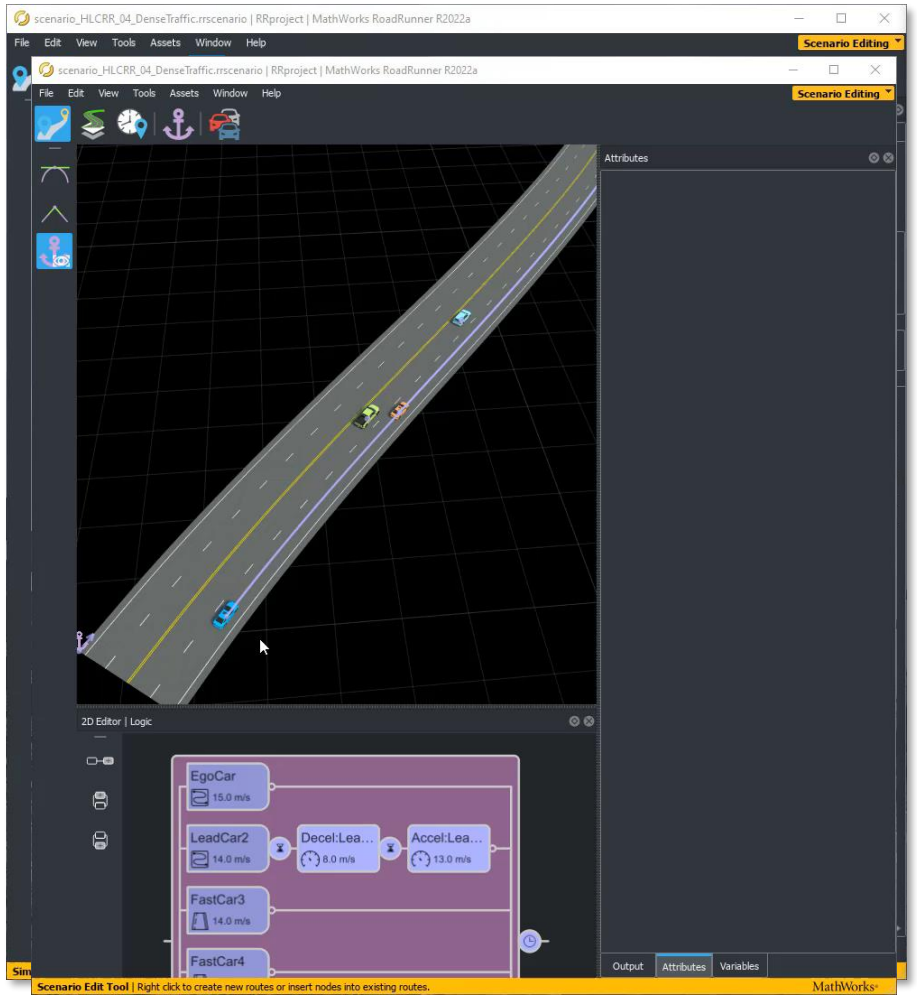
[AEB Euro NCAP Testing with RoadRunner Scenario]

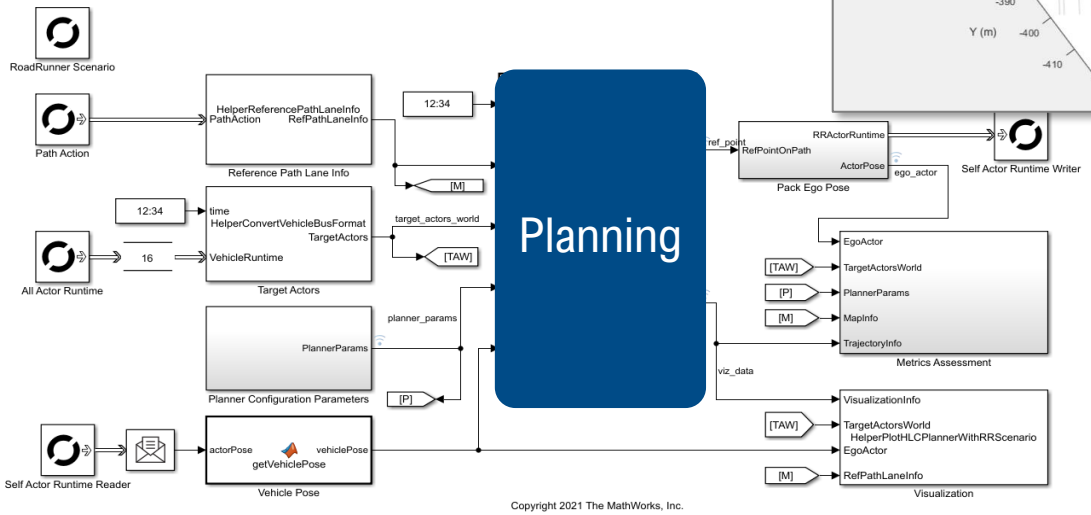
Automated Driving Toolbox, RoadRunner Scenario, Simulink Test

Simulate highway lane change planner

- Planner reads path action, map data, and all actor runtime from RoadRunner Scenario
- Finds optimal collision-free trajectory to navigate ego vehicle
- MATLAB used for visualization and metrics assessment





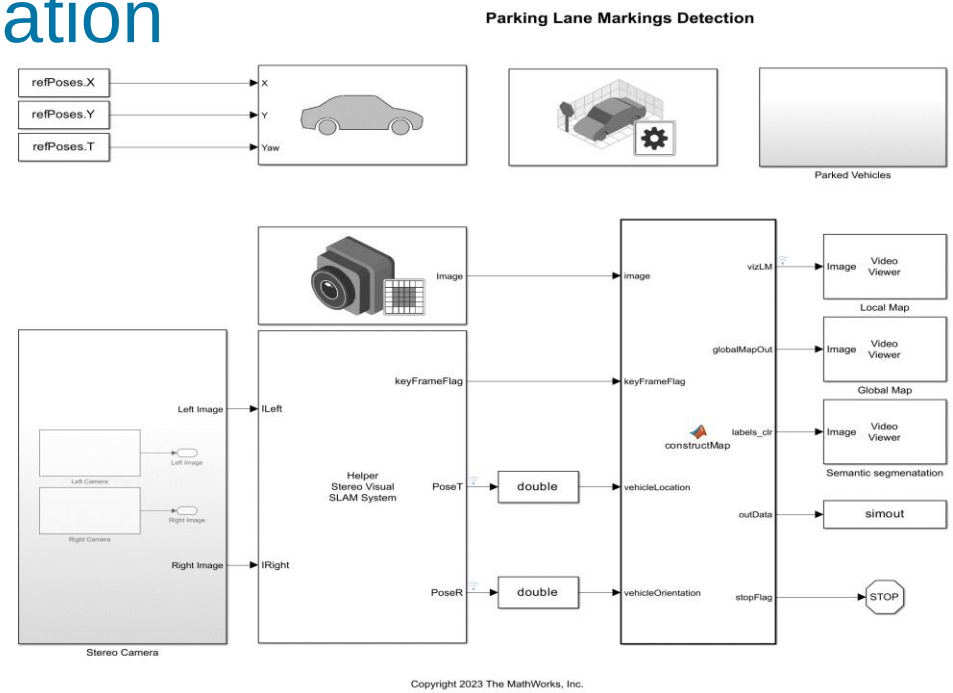


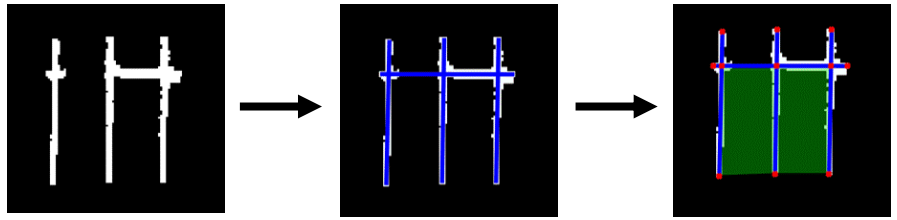
[Highway Lane Change Planner with RoadRunner Scenario]

Automated Driving Toolbox, RoadRunner Scenario, Simulink, Navigation Toolbox

Develop parking spot detection with simulation

- Configure 3D scene with built-in parking lot example scene and a reference trajectory
- Side-mounted camera maps the environment and a front-facing stereo camera is used for SLAM
- Localization and perception algorithms build local maps to detect parking spots





Build a local line marker map using SLAM

Detect parking line markers and vehicles using deep learning

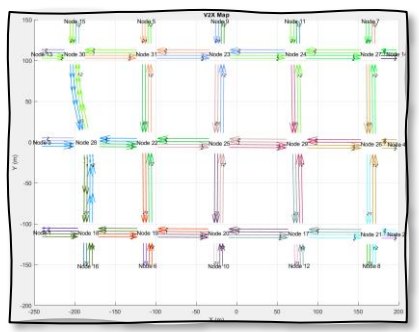
Determine if a parking spot is present and if it is occupied

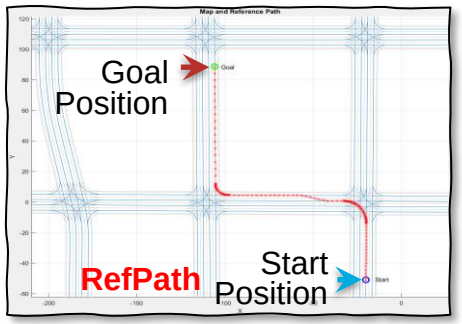
[Perception Based Live Parking Spot Detection Using Unreal Engine Simulation]

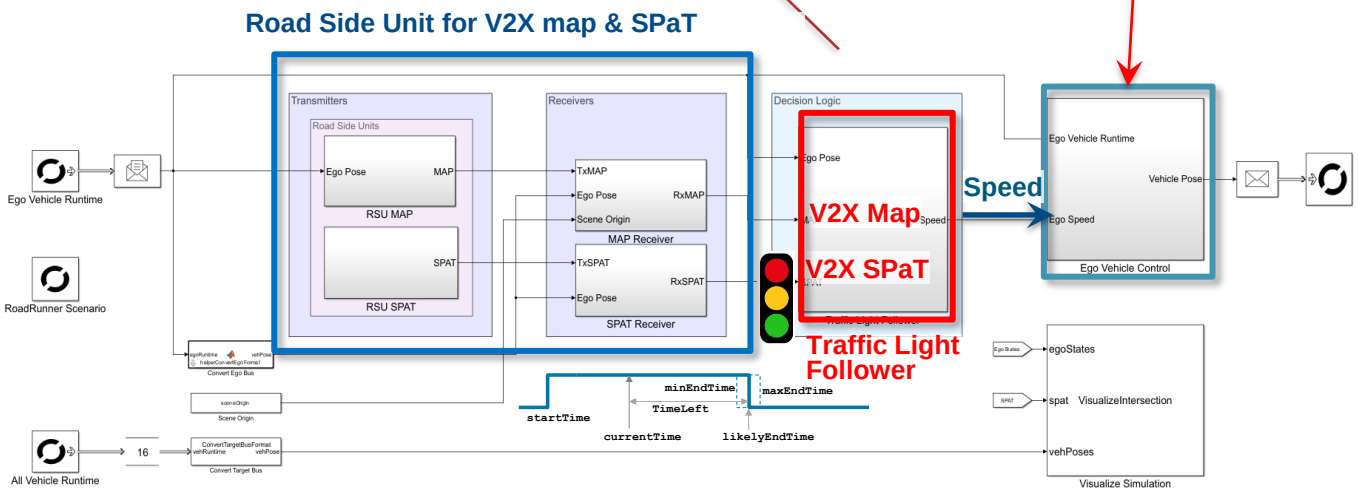
Automated Driving Toolbox, Computer Vision Toolbox, Simulink

R2023b

Traffic Light Follower at the intersection

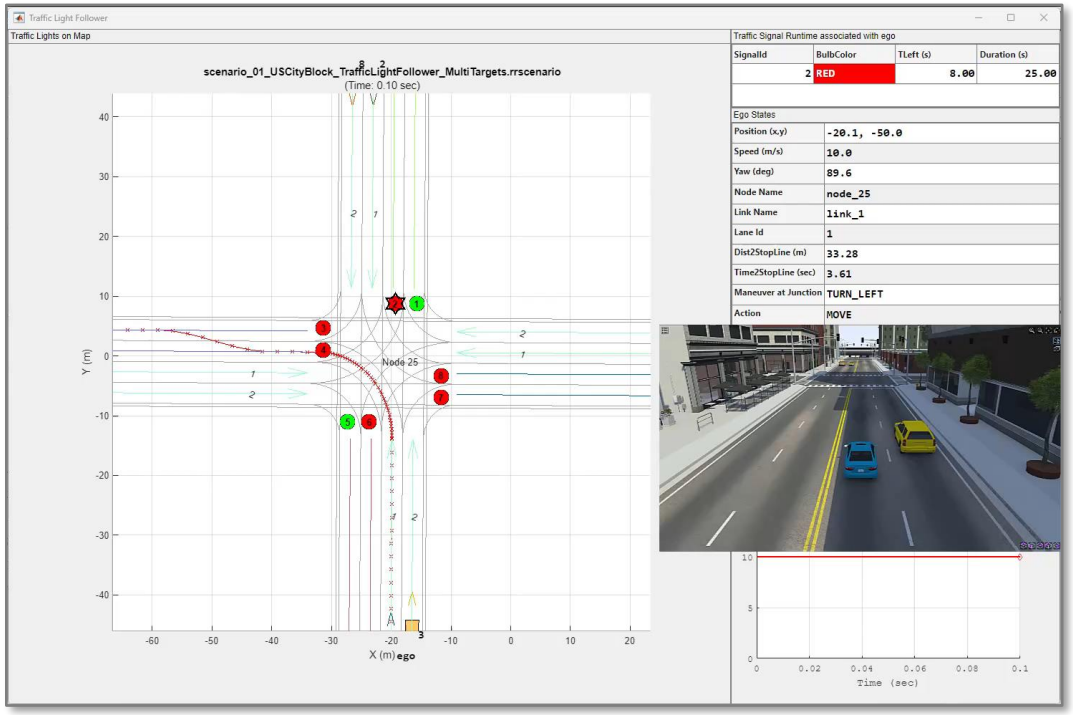






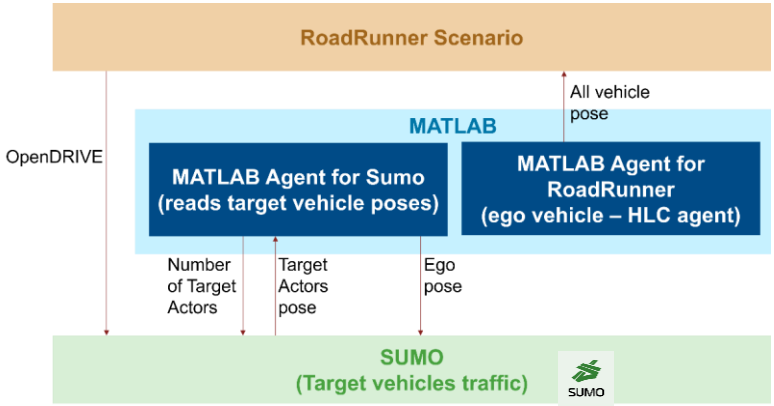
C-V2X standard:

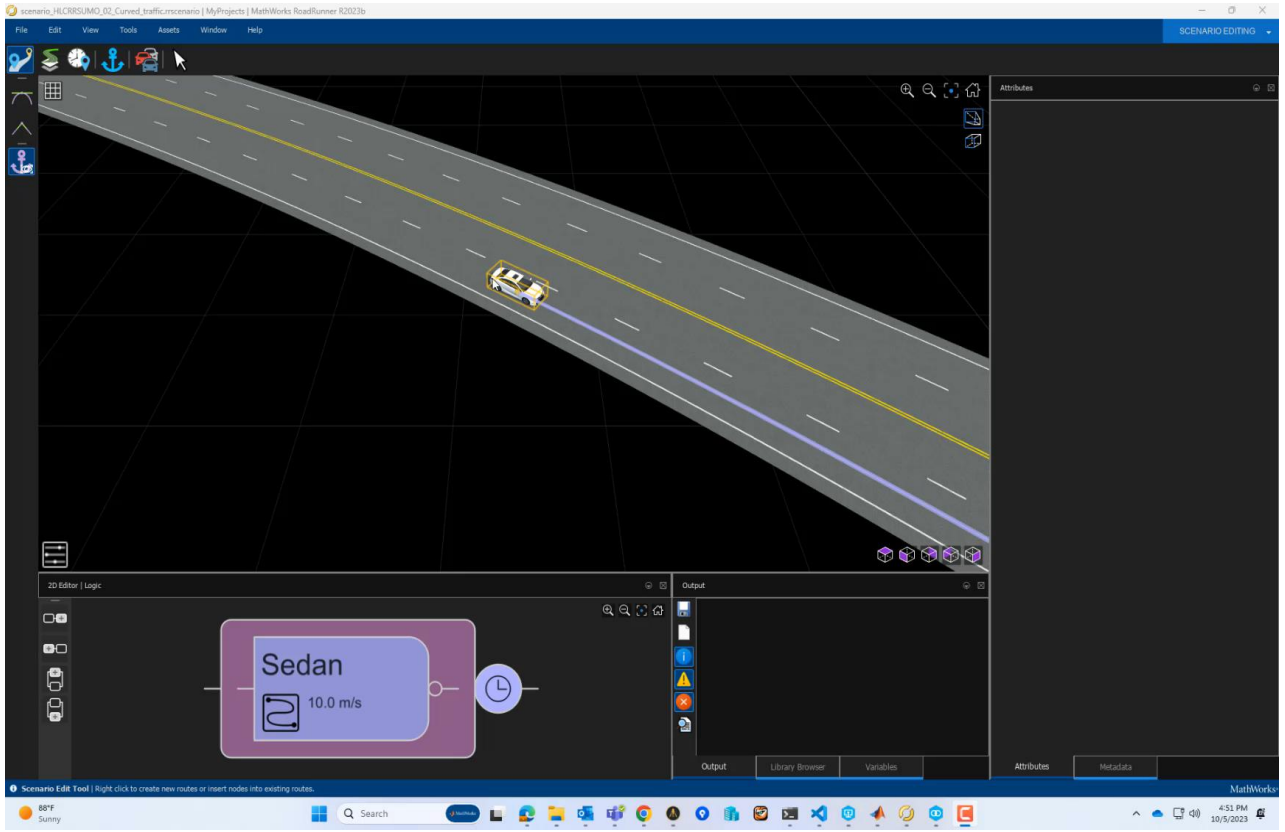
- T/CSAE 53-2020,
- SAE J2735



Stochastic traffic flow simulation with sumo

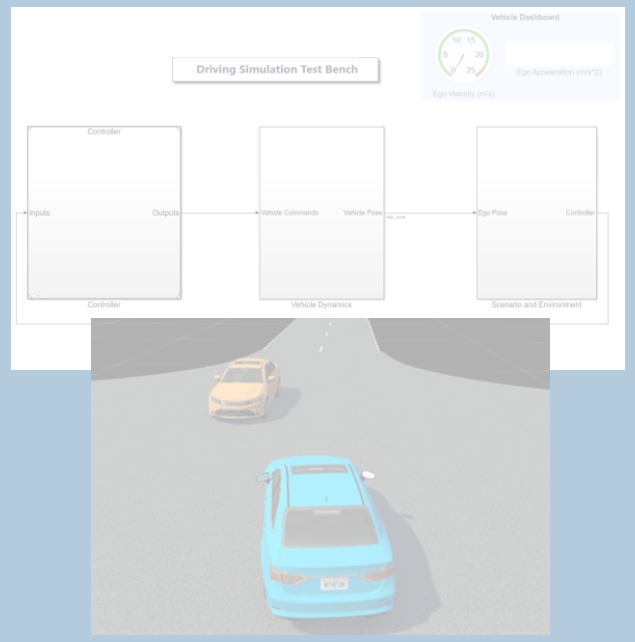
- A generic toolbox in Simulink
- Co-simulate SUMO with Simulink without coding
- Easy to control simulation and access actors
- Bring traffic scenario and sensors to Simulink
- Support multi-platforms/cloud platform, CI/CD



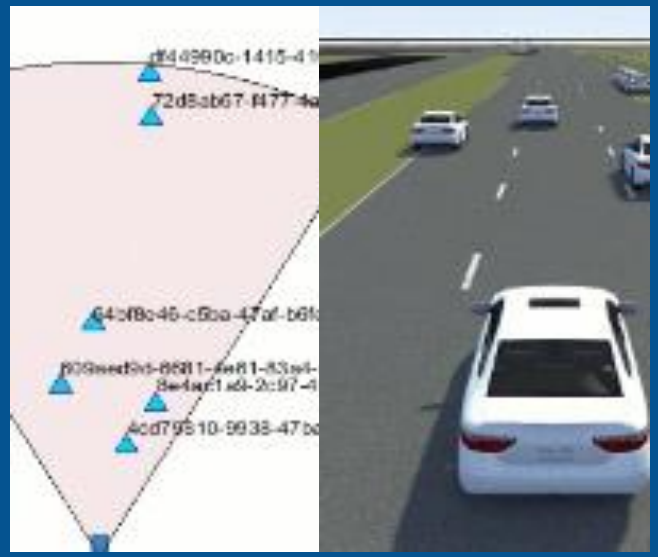


Develop automated driving scenarios with MATLAB, Simulink, and RoadRunner

Design scenes & scenarios for common driving simulation tools



Simulate driving applications for early design and test



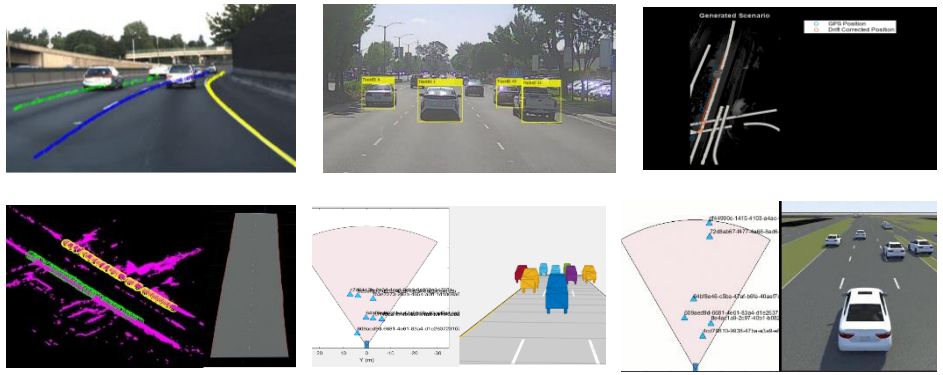
Build scenarios from maps and recorded sensor data

Build scenes and scenarios from custom map and sensor data

- Camera images
- Lidar point clouds
- GPS
- IMU
- Map Data

Automated Driving Toolbox

Scenario Builder Support Package



- OpenSCENARIO v1.x
- CSV Trajectories

RoadRunner Scene Builder

RoadRunner Scenario

Lidar Toolbox

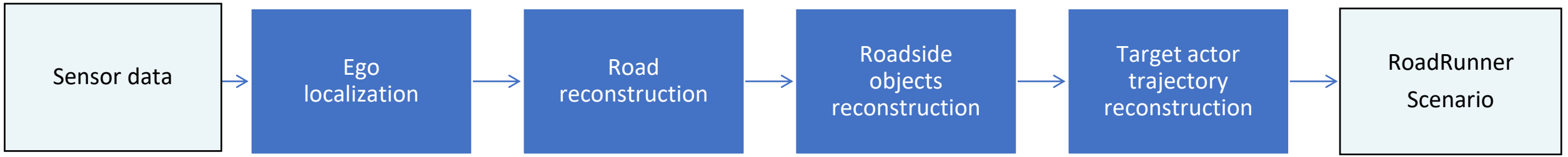
Computer Vision Toolbox

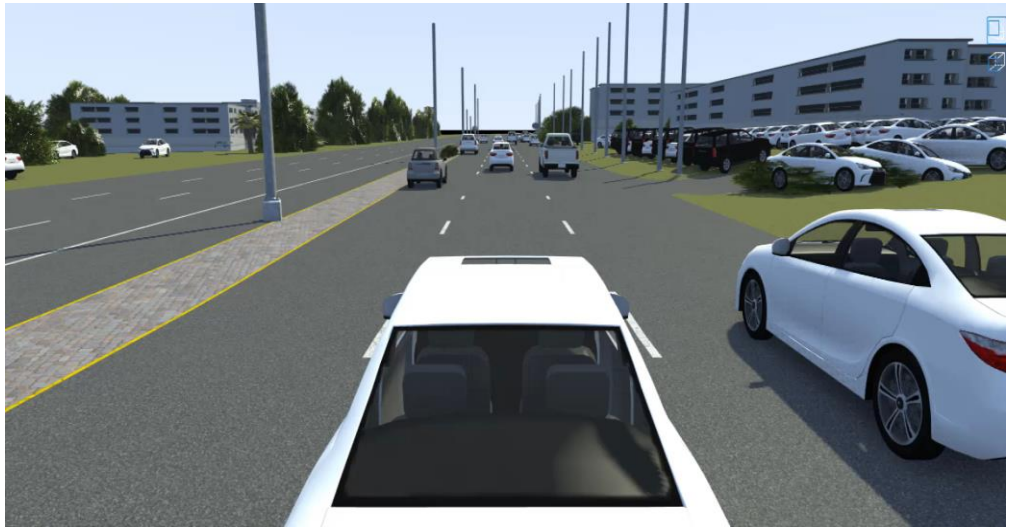
Deep Learning Toolbox

Sensor Fusion & Tracking Toolbox

Navigation Toolbox

Generate scenarios from recorded sensor data





Sensor data used for this reconstruction:
Camera images: Lanes
Lidar point cloud: Vehicles
Labelled data: Trees, Buildings, Poles

Scenario Builder (Support Package)
Automated Driving Toolbox

Learn about new examples to build scenarios from recorded data

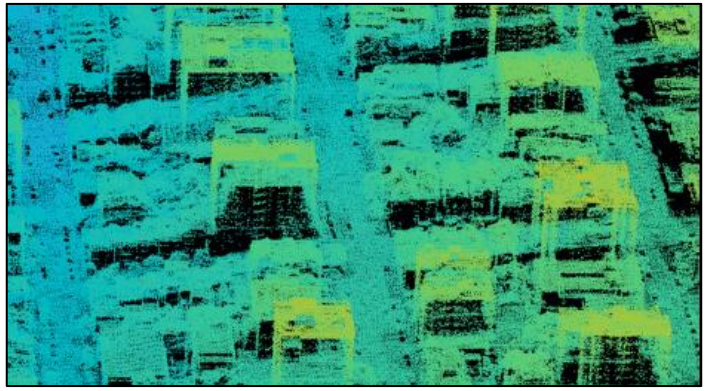
Reconstruct Traffic Signs

[Generate RoadRunner Scene with Traffic Signs Using Recorded Sensor Data]

Scenario Builder for Automated Driving Toolbox, Lidar Toolbox, Sensor Fusion and Tracking Toolbox

R2023b

Aerial Data to 3D Scene

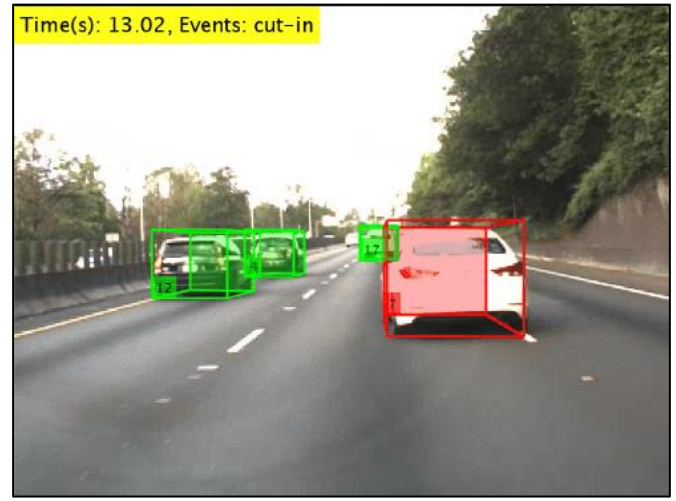


[Generate RoadRunner Scene Using Aerial Lidar Data]

Scenario Builder for Automated Driving Toolbox, Lidar Toolbox, Mapping Toolbox

R2023b

Extract Key Events

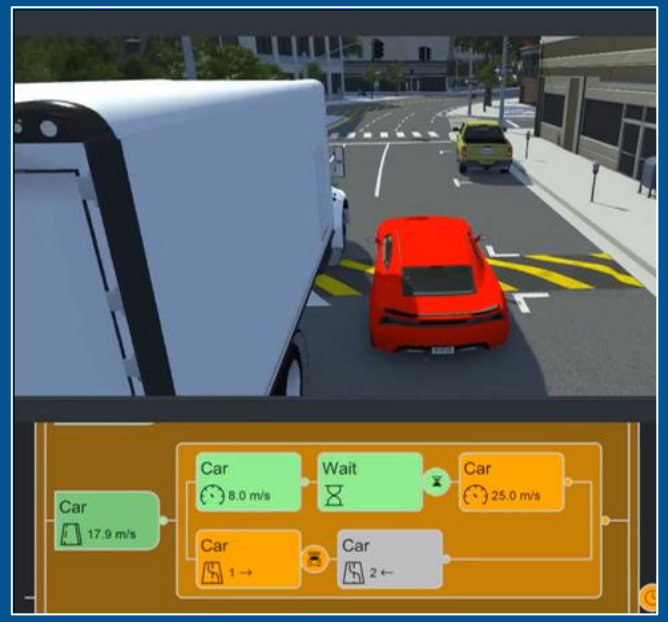


[Extract Key Scenario Events from Recorded Sensor Data]

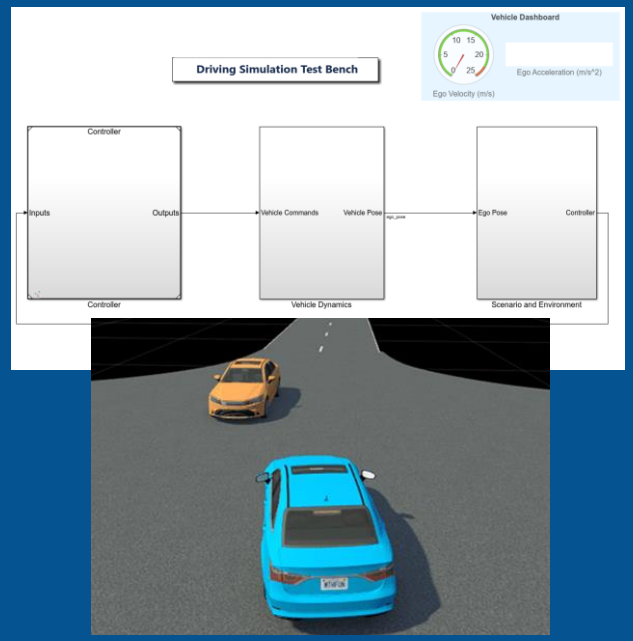
Scenario Builder for Automated Driving Toolbox, Sensor Fusion and Tracking Toolbox

R2023b

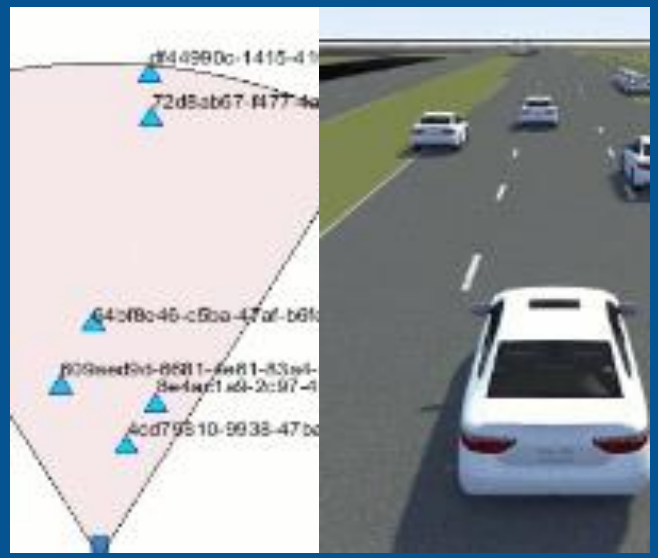
Develop automated driving scenarios with MATLAB, Simulink, and RoadRunner



Design scenes & scenarios for common driving simulation tools



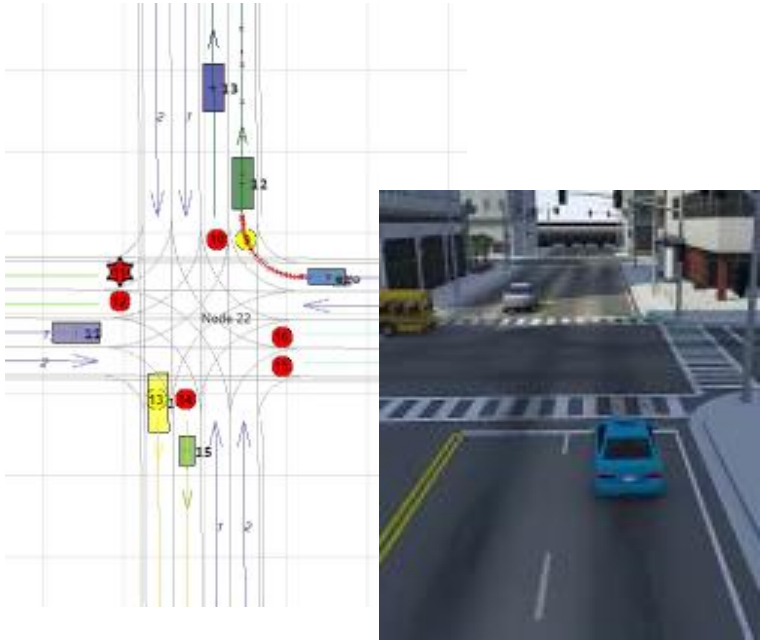
Simulate driving applications for early design and test



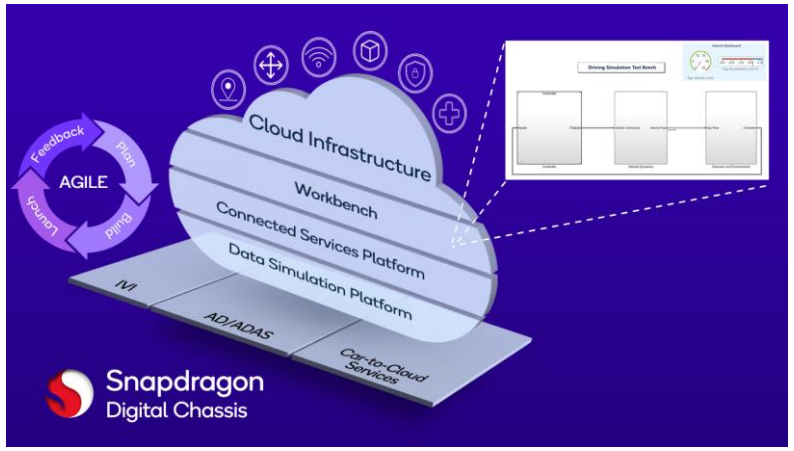
Build scenarios from maps and recorded sensor data

Partner with MathWorks to develop automated driving systems

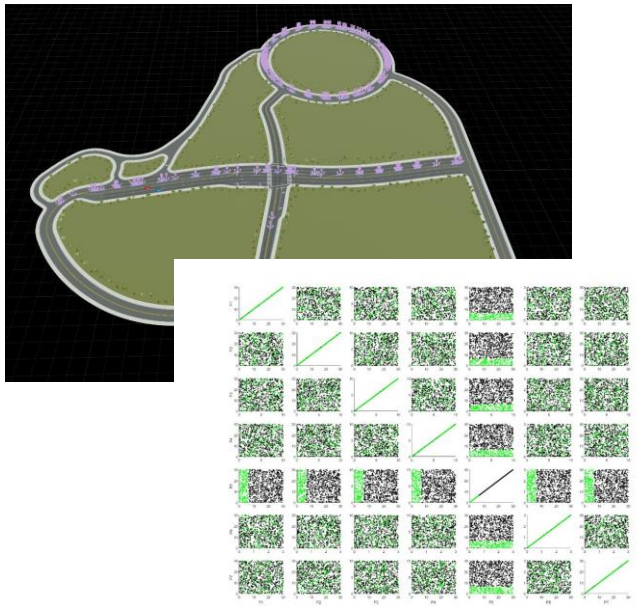
Model Traffic Light Follower



Qualcomm Automotive Development Platform



Reduce Scenario Hyperspaces

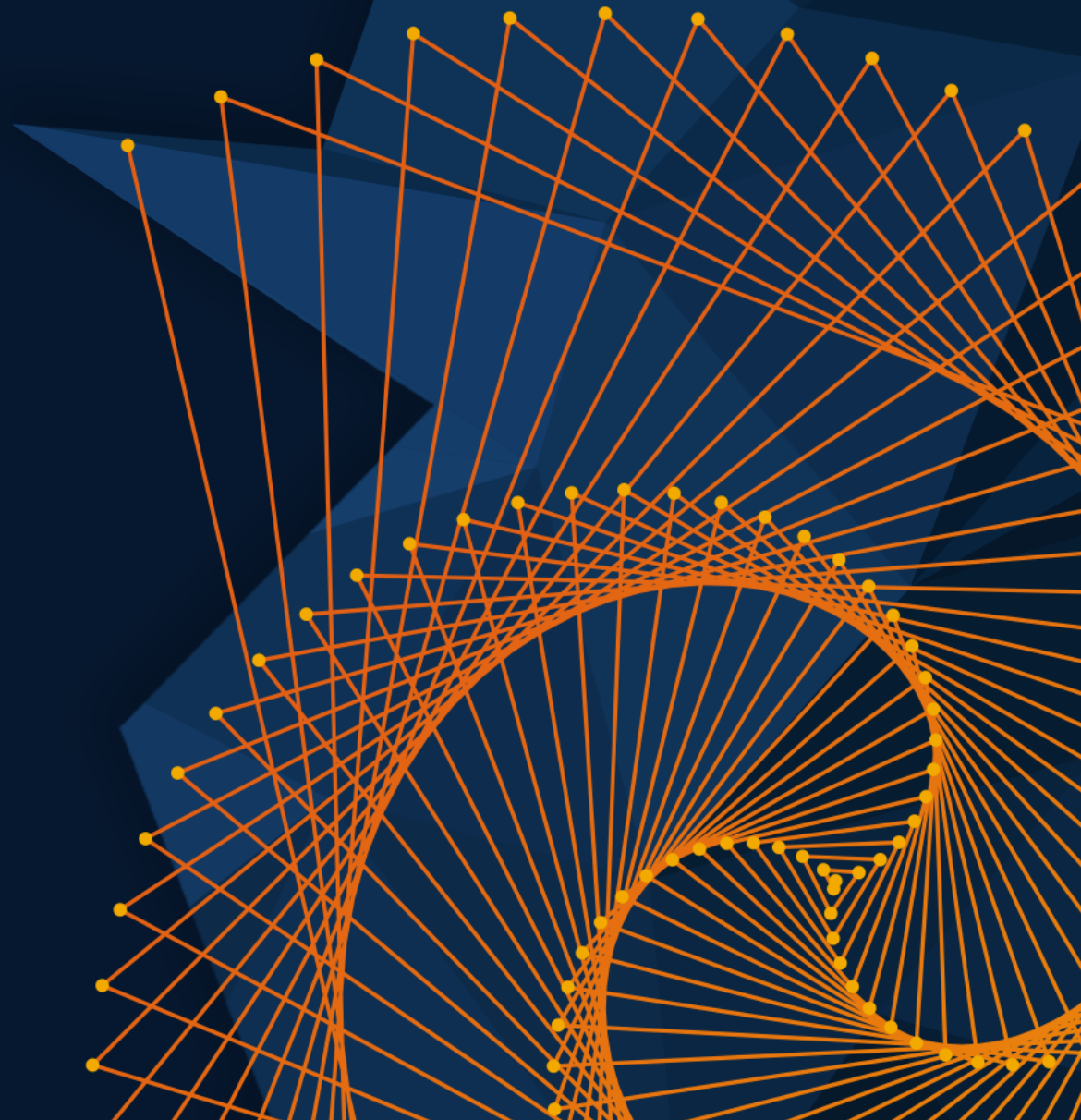


Engage with MathWorks engineers through proof-of-concept or Consulting Services engagements to extend workflows to meet the needs of your projects

automated-driving@mathworks.com

MATLAB EXPO

Thank you



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