MATLAB EXPO
2021

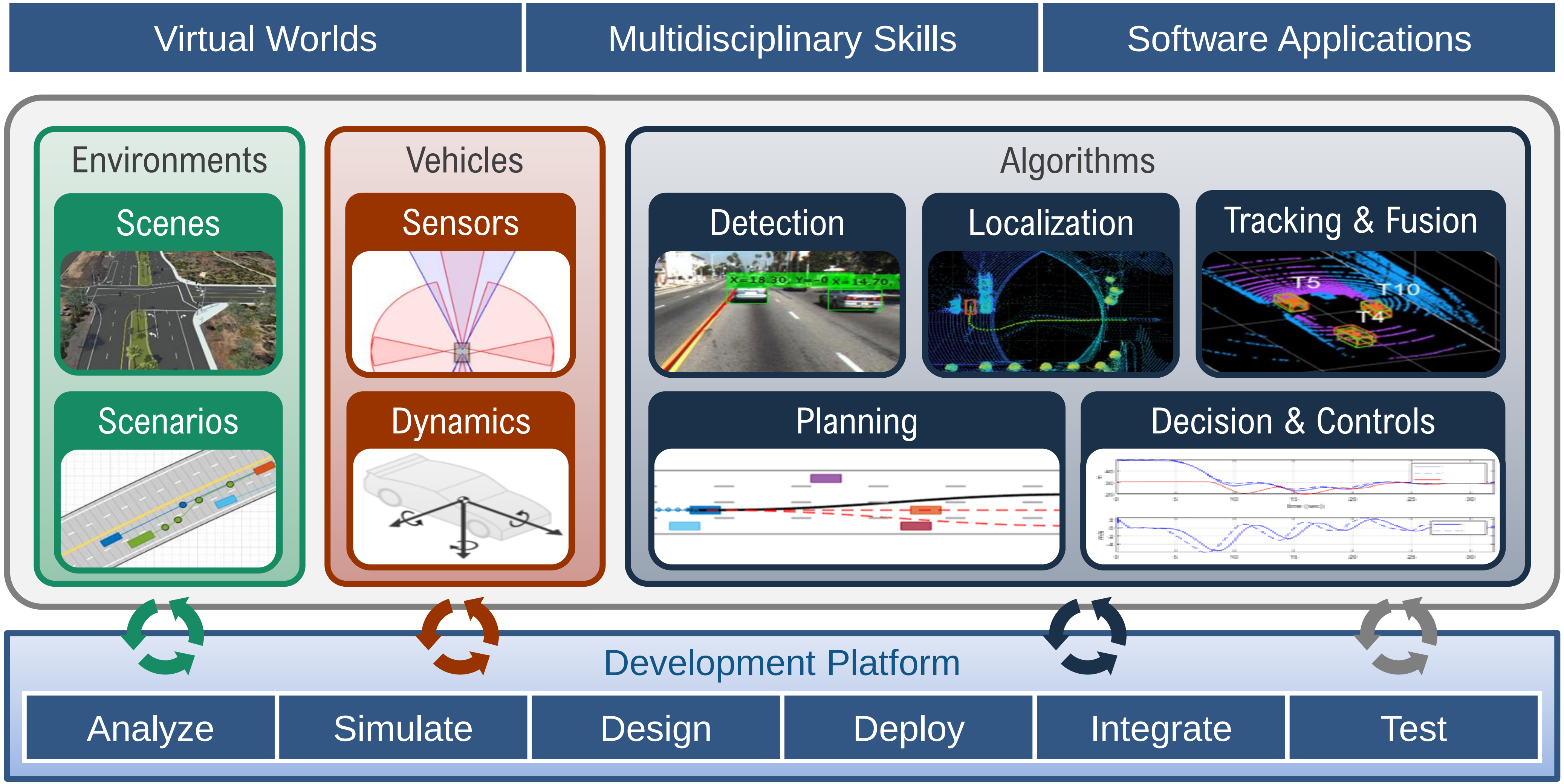
What's New in MATLAB & Simulink for Automated Driving Development

Mark Corless

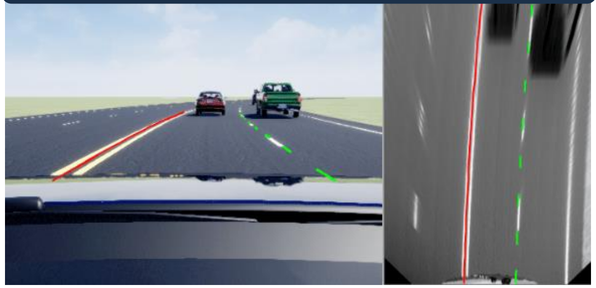
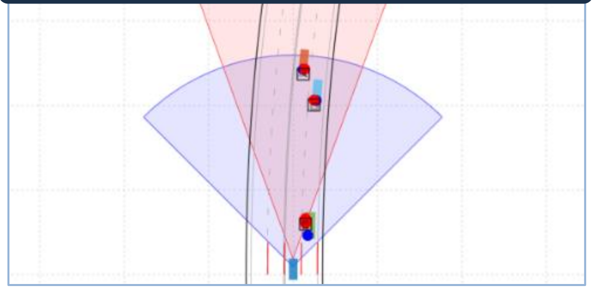
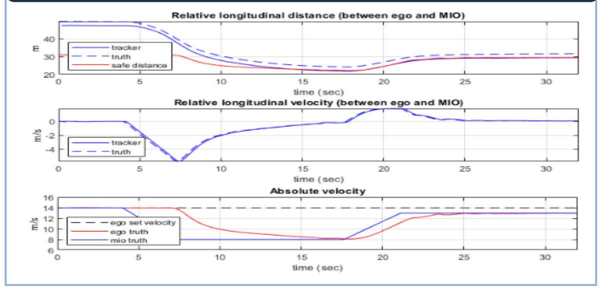
MathWorks®

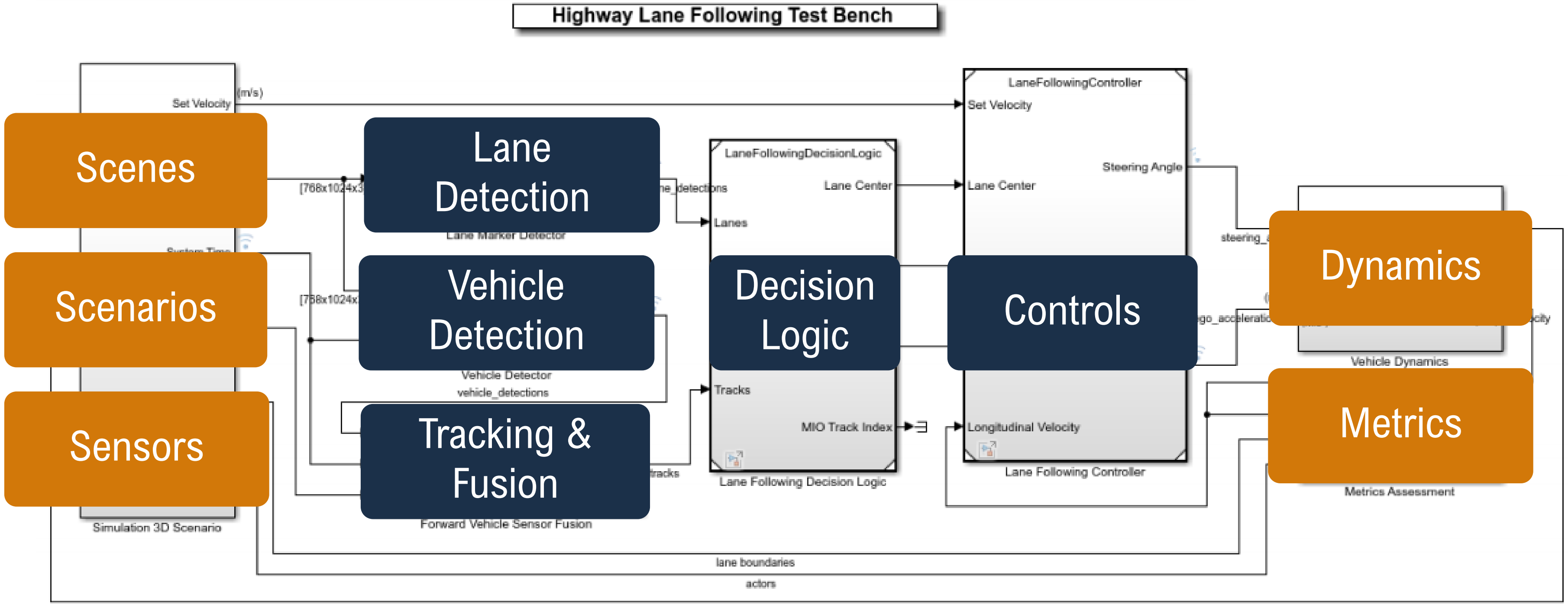
Develop Automated Driving Systems

with MATLAB, Simulink, and RoadRunner



Simulate automated driving systems in virtual worlds

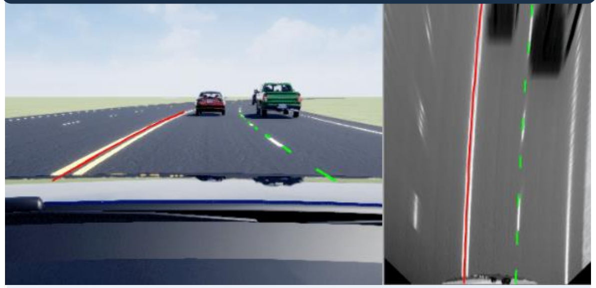
Lane Detections	Vehicle Detections	Tracking & Fusion	Decision & Controls
			

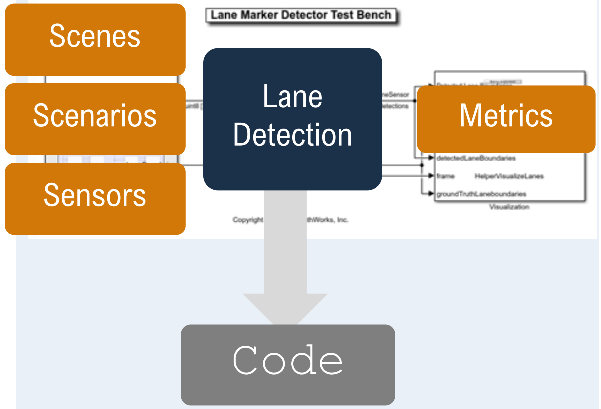


[Highway Lane Following]()

Develop automated driving algorithms for multiple disciplines

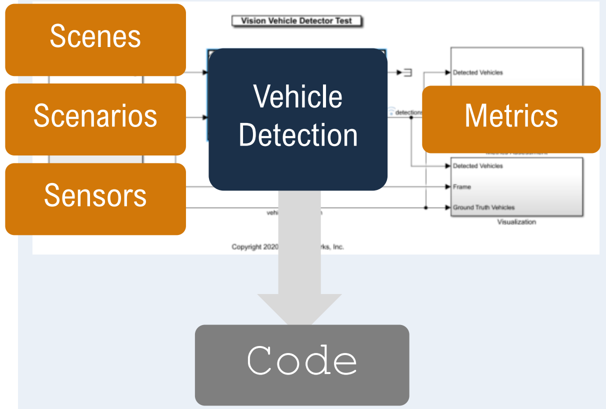
Lane Detections





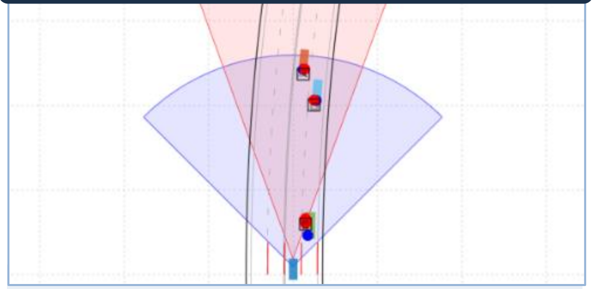
Lane Detector

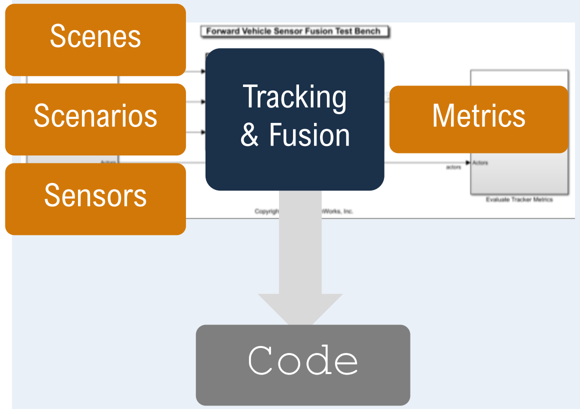
Vehicle Detections



Vehicle Detector

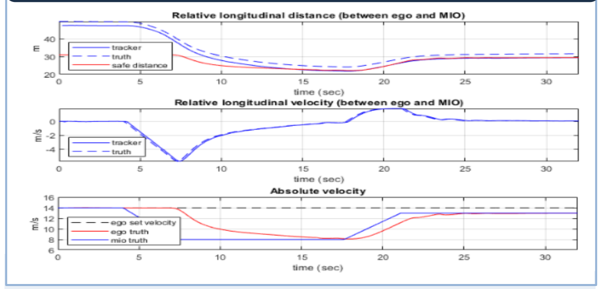
Tracking & Fusion

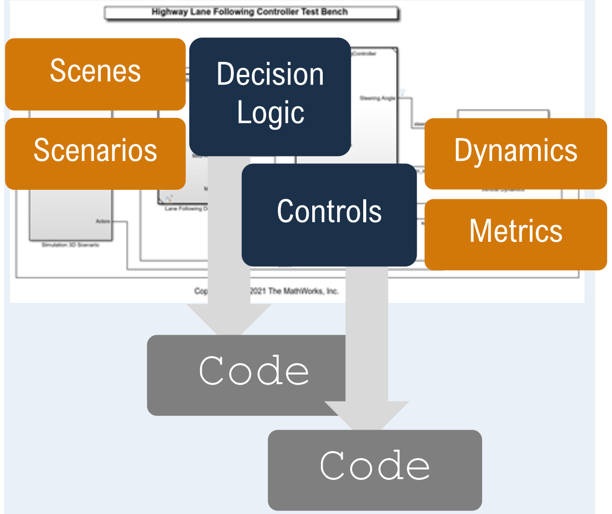




Vehicle Sensor Fusion

Decision & Controls

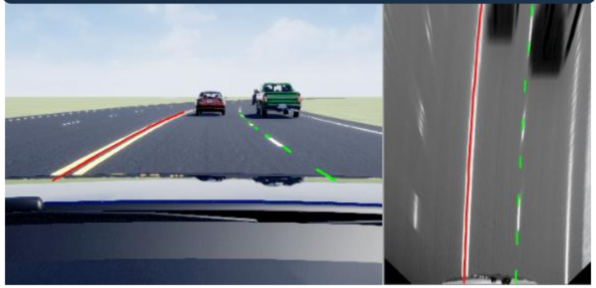




Decision and Controls

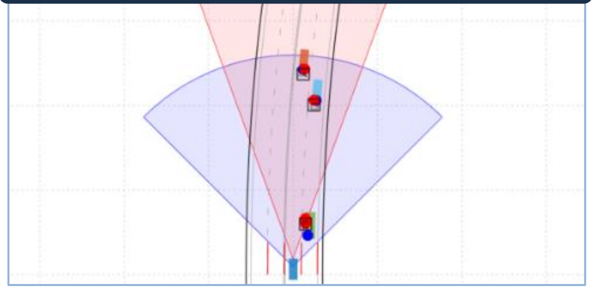
Develop software applications for automated driving

Lane Detections

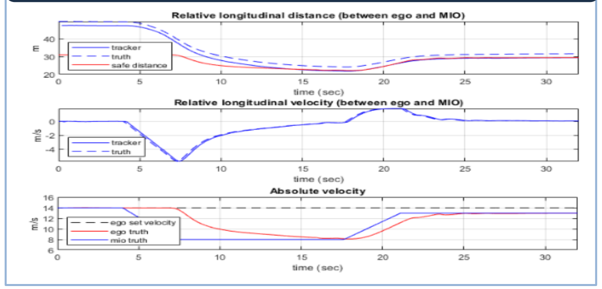


Vehicle Detections

Tracking & Fusion

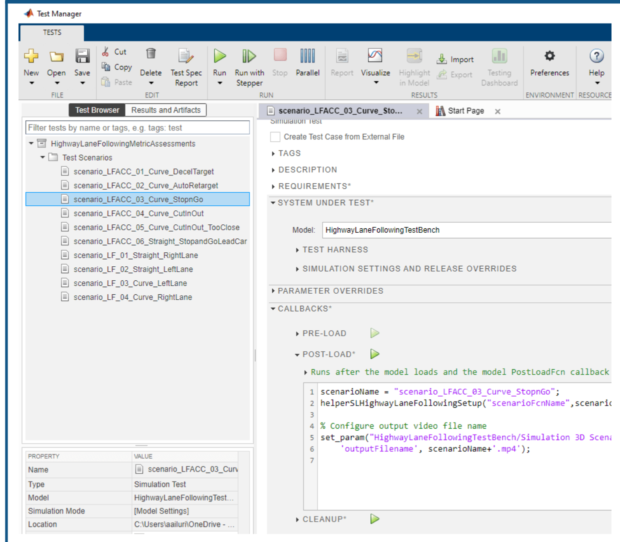


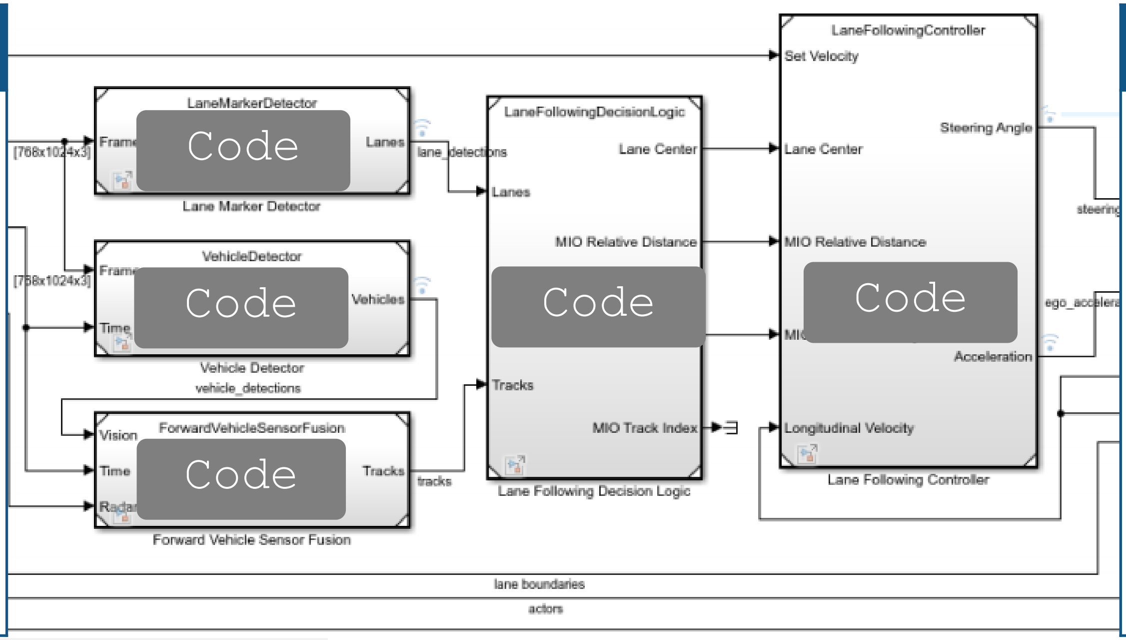
Decision & Controls



Highway Lane Following Test Bench

Manage Tests





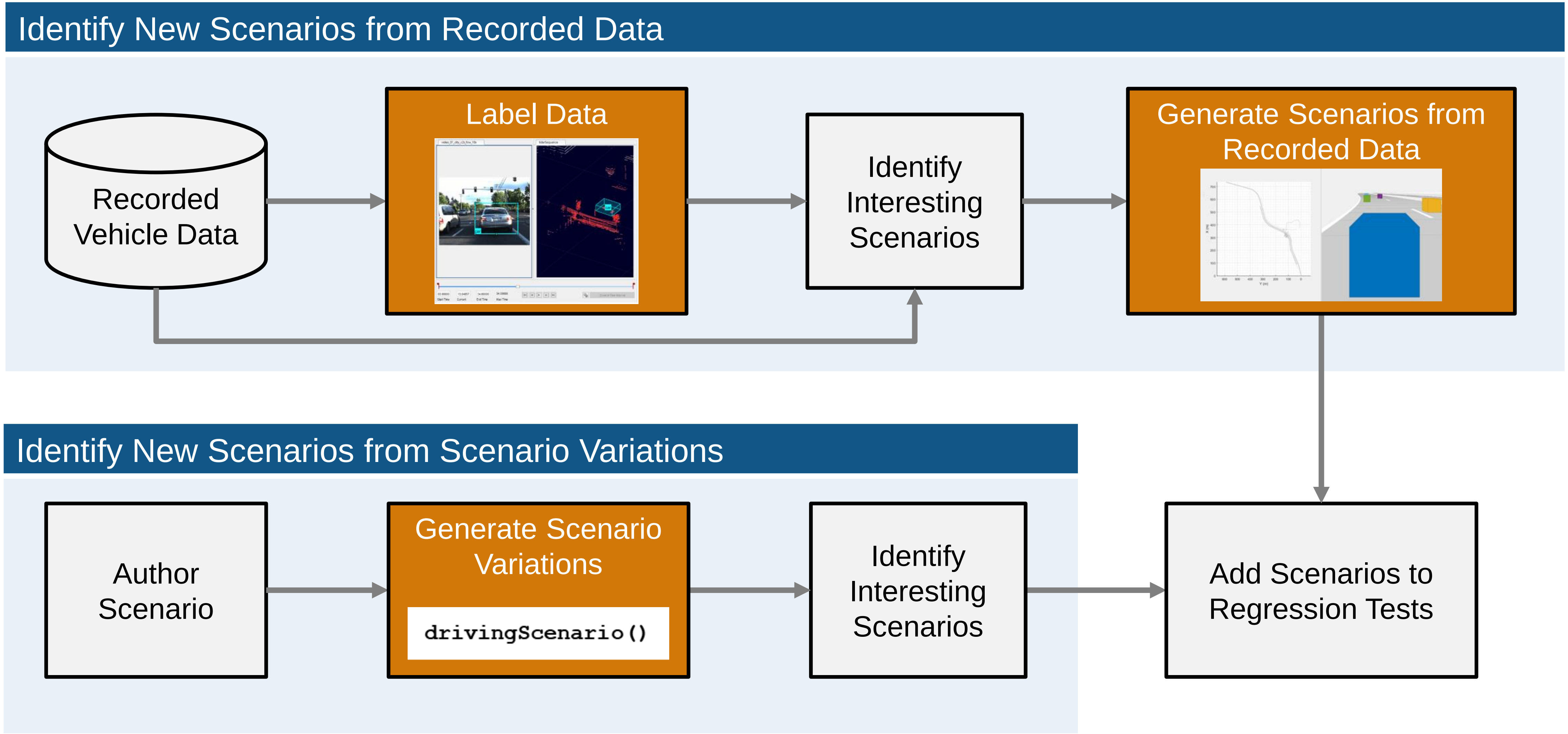
Report Results

Summary

Name	Outcome
HighwayLaneFollowingMetricAssessments	10 ✔
Test Scenarios	10 ✔
scenario_LFACC_01_Curve_DecelTarget	✔
scenario_LFACC_02_Curve_AutoRetarget	✔
scenario_LFACC_03_Curve_StopnGo	✔
scenario_LFACC_04_Curve_CutInOut	✔
scenario_LFACC_05_Curve_CutInOut_TooClo	✔
scenario_LFACC_06_Straight_StopandGoLea	✔
scenario_LF_01_Straight_RightLane	✔
scenario_LF_02_Straight_LeftLane	✔
scenario_LF_03_Curve_LeftLane	✔
scenario_LF_04_Curve_RightLane	✔

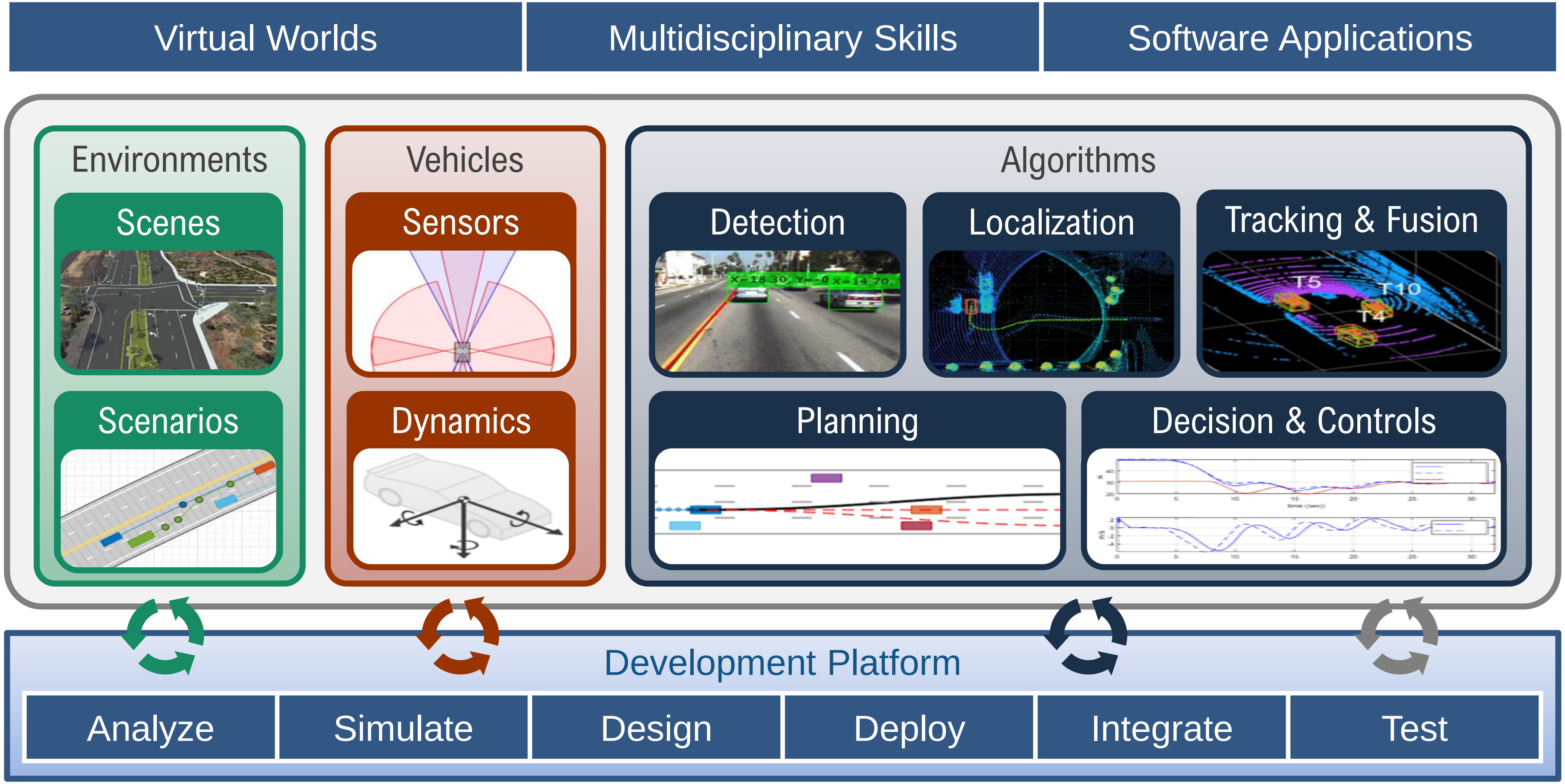
[Automate Testing of Highway Lane Following]

Extend workflows to identify new scenarios to test



Develop Automated Driving Systems

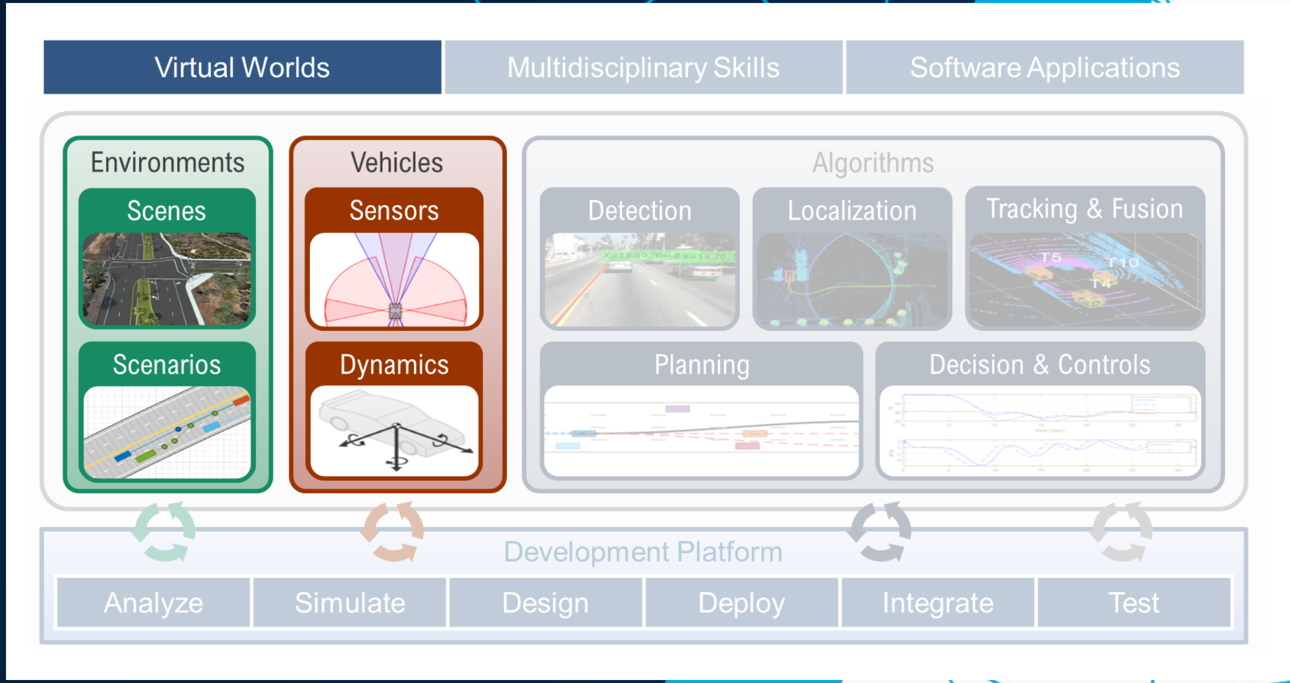
with MATLAB, Simulink, and RoadRunner



MATLAB EXPO 2021

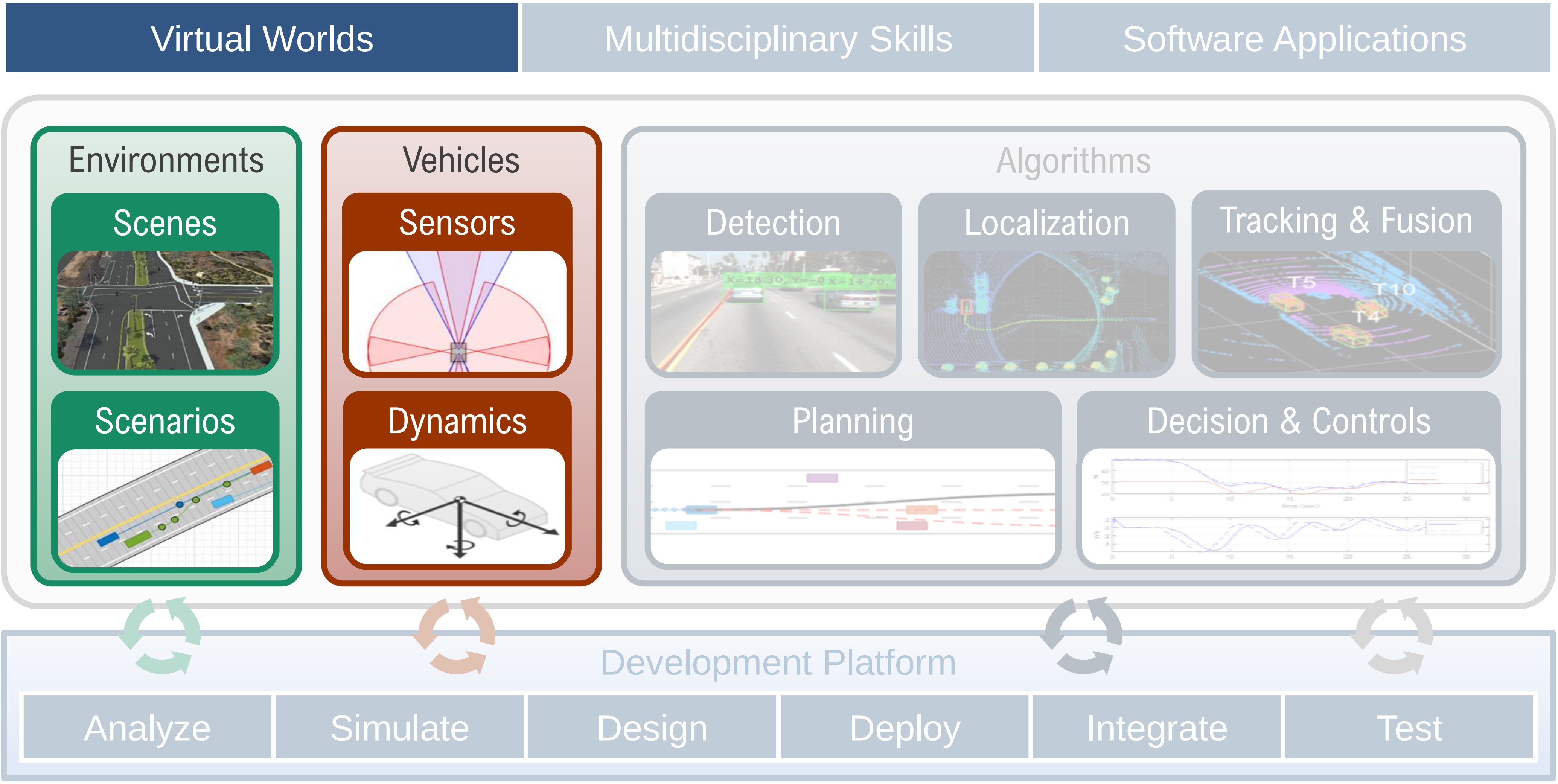
Develop Virtual Worlds for Automated Driving

Rashmi Gopala Rao



MathWorks

Develop virtual worlds for automated driving systems



Design 3D scenes for automated driving applications

OpenDRIVE

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

Custom Assets

Design Scenes

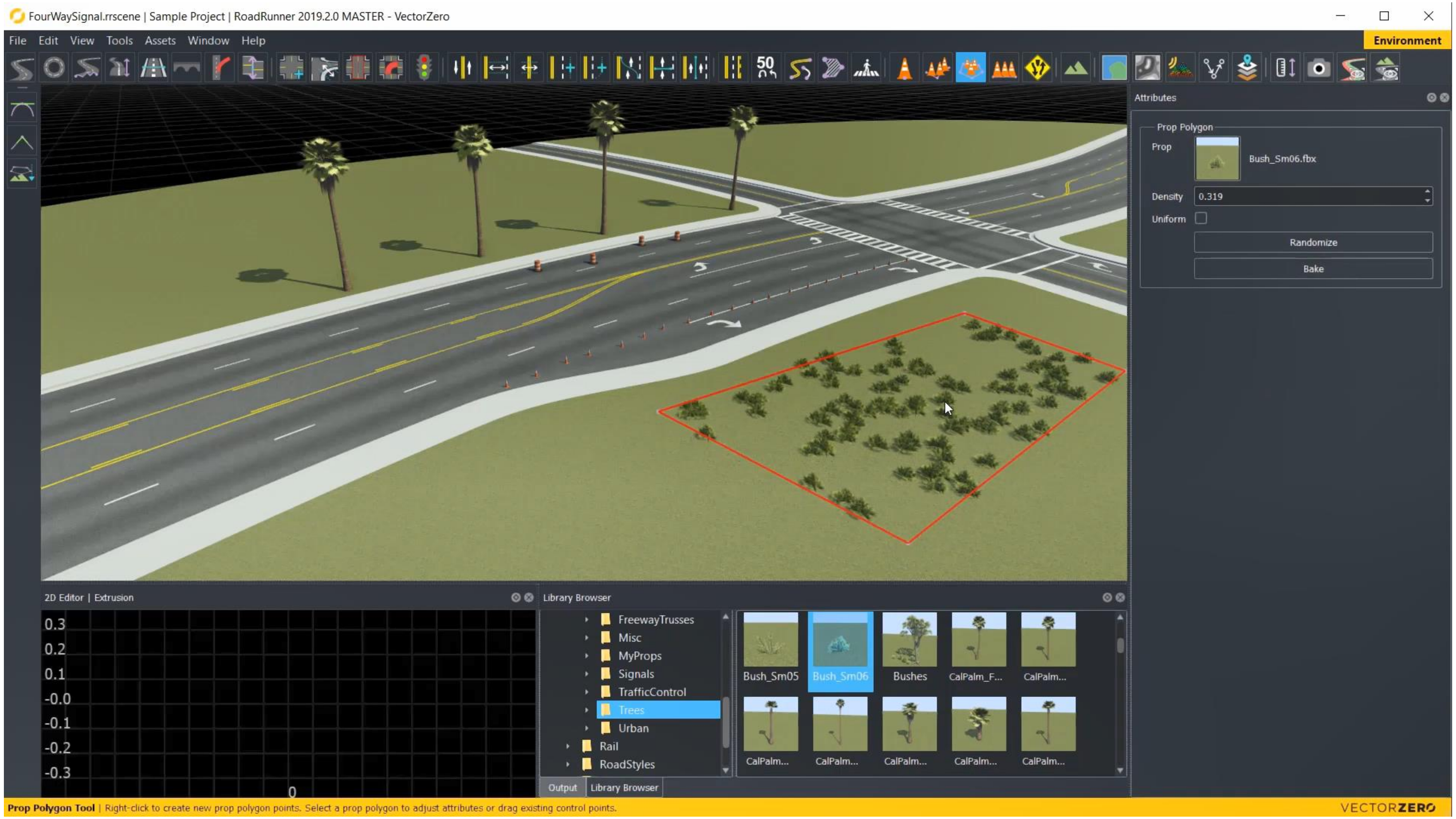
RoadRunner

OpenDRIVE

Filmbox

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

Interactively design 3D scenes in RoadRunner



Design 3D scenes for automated driving applications

Here HD Live Map

OpenDRIVE

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

Custom Assets

Design Scenes

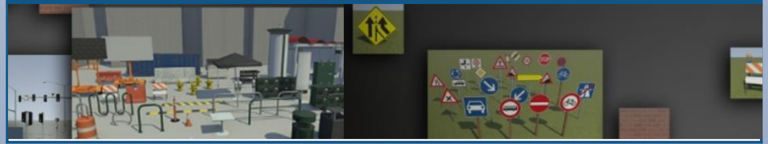
RoadRunner Scene Builder

R2020b

RoadRunner

R2020a

RoadRunner Asset Library



R2020a

OpenDRIVE

Filmbox

Third Party Simulators
- CARLA
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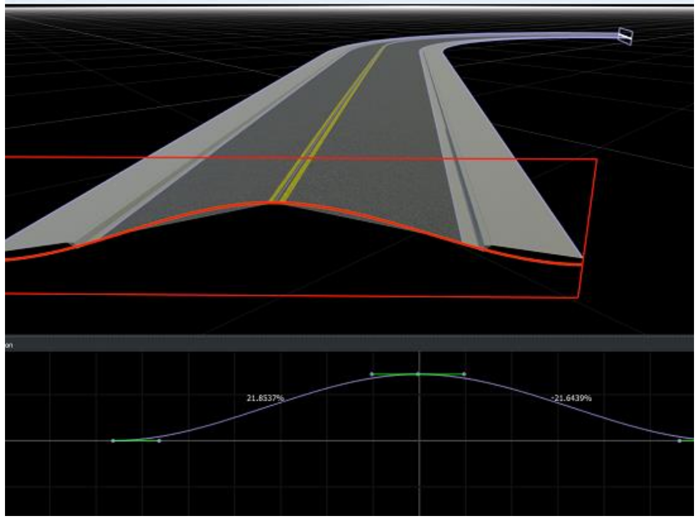
- Tesis Dynaware
- TaSS PreScan
- NVIDIA DRIVE Sim through Universal Scene Description (USD)

Learn about new features to design 3D scenes

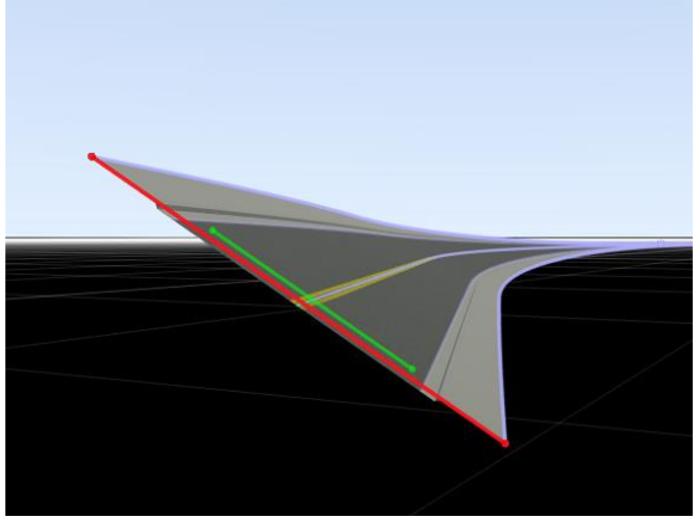
Design Lateral Profile



[Cross Section Tool](#)
RoadRunner

R2021a

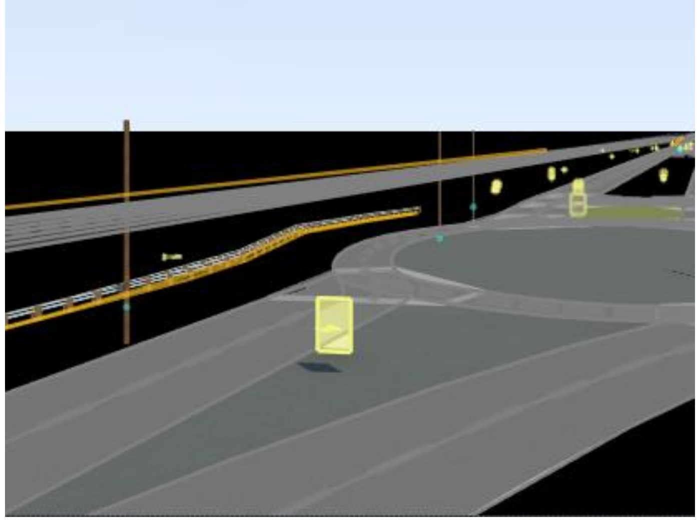
Design Superelevation



[Road Superelevation Tool](#)
RoadRunner

R2021a

Import signs, poles, and barriers from HERE



[Configure Assets to Use for Imported HERE HD Live Map Data](#)
RoadRunner Scene Builder

R2021a

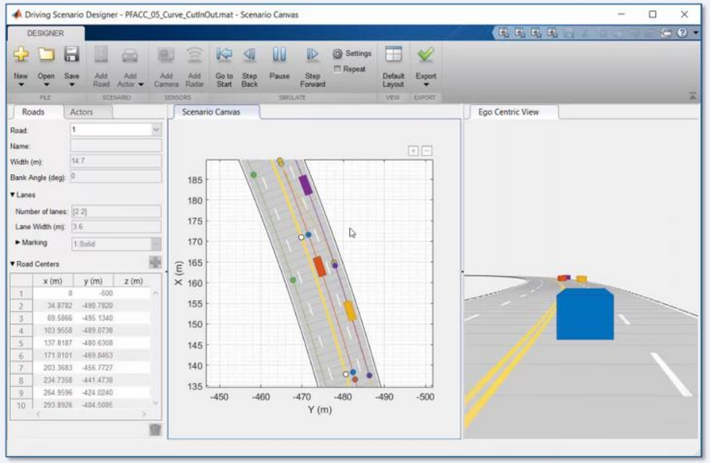
Design scenes and scenarios for automated driving

OpenDRIVE
OpenStreetMap
HERE HD Maps
Zenrin SD

Custom meshes

Design Driving Scenarios

Driving Scenario Designer App



Driving Scenario API

```
ds = drivingScenario();
```

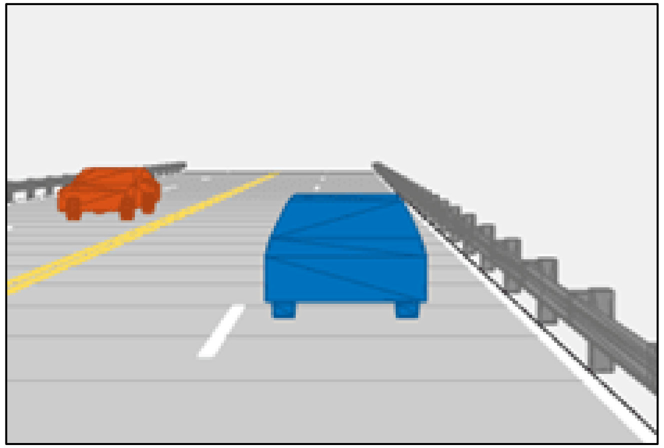
Driving scenario
- Roads
- Lane markings
- Barriers & guardrails
- Vehicle trajectories

OpenDRIVE

OpenSCENARIO

Learn about new features to design scenes and scenarios (1 of 2)

Add guardrails and barriers

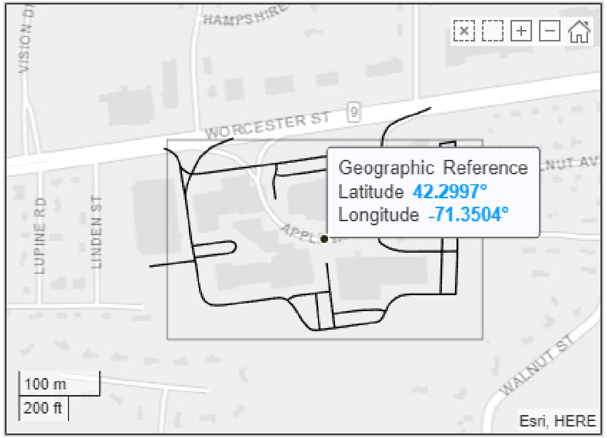


Driving Scenario Designer

Automated Driving Toolbox™

R2021a

Import OpenStreetMap

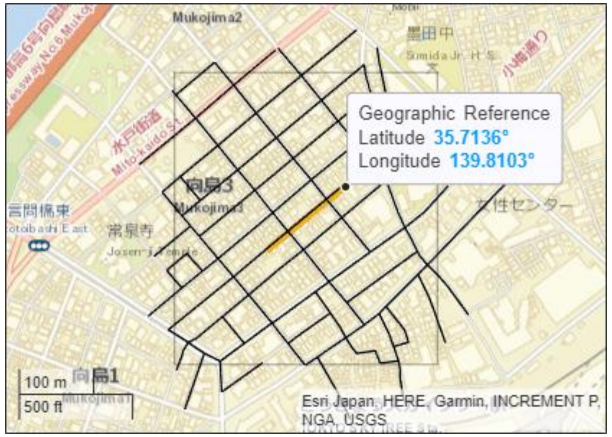


Import OpenStreetMap Data into Driving Scenario

Automated Driving Toolbox™

R2021a

Import Zenrin Maps



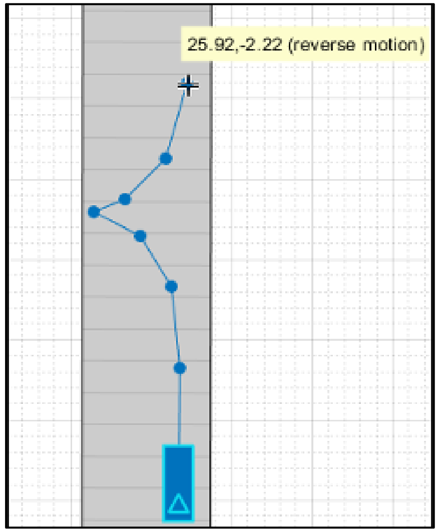
Import Zenrin Japan Map API 3.0 (Itsumo NAVI API 3.0) into Driving Scenario

Automated Driving Toolbox™

R2021a

Learn about new features to design scenes and scenarios (2 of 2)

Specify reverse motion

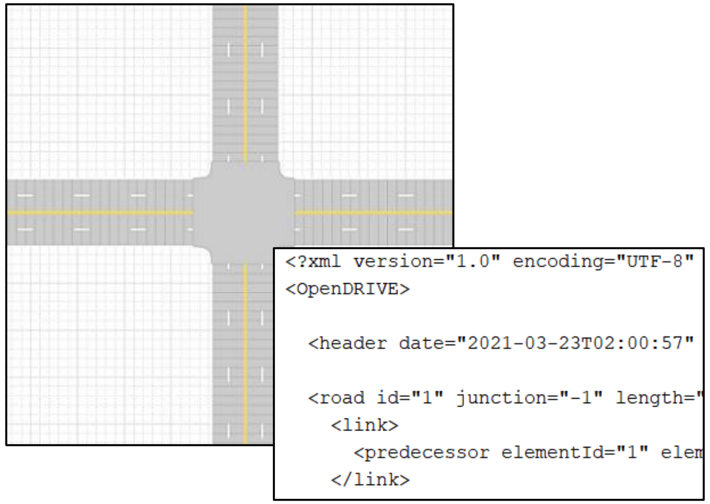


Create Reverse Motion Driving Scenarios Interactively

Automated Driving Toolbox™

R2020b

Export to OpenDRIVE® 1.4H



Export Driving Scenario to OpenDRIVE File

Automated Driving Toolbox™

R2020b

Export to OpenSCENARIO® 1.0

Triggers

- Simulation time
- Actor absolute position

Actions

- Start routing/trajectory action
- Set target speed
- Change speed
- Add/remove actors

Export driving scenario to OpenSCENARIO

Automated Driving Toolbox™

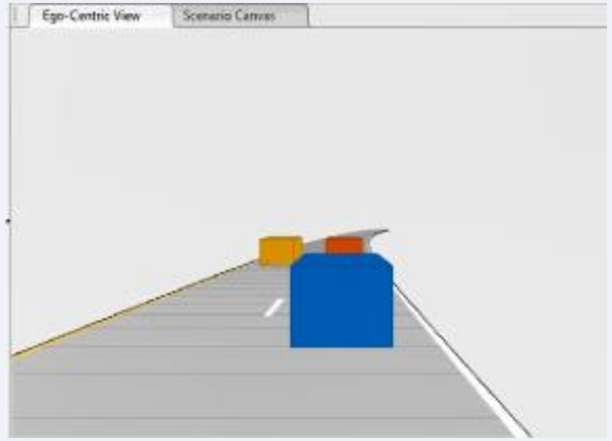
R2021a

Simulate scenes and scenarios for automated driving

Design Scenes with RoadRunner

Design Driving Scenarios

Simulate with Cuboids



Typical Uses:

- Simulate controls, planning, tracking & fusion
- Simulate systems requiring truth or detection level sensors

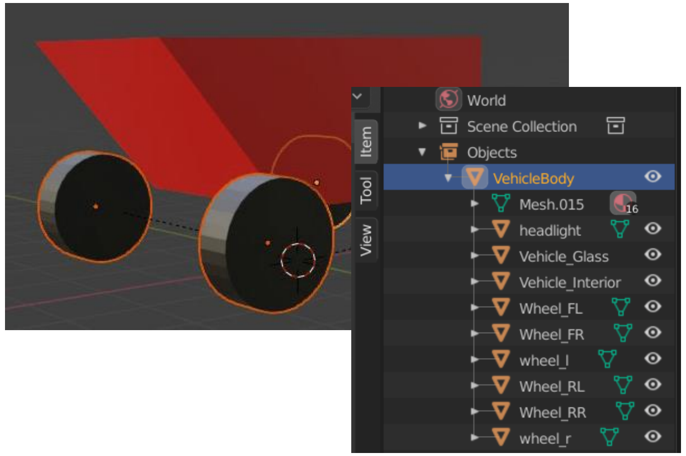
Simulate with Unreal Engine® from Epic Games®

Typical Uses:

- Simulate systems which include detection and localization
- Visualize systems where underlying simulation is performed with cuboids

Learn about new features to simulate with Unreal Engine

Custom meshes



Prepare Custom Vehicle Mesh for the Unreal Editor

Automated Driving Toolbox™

R2021a

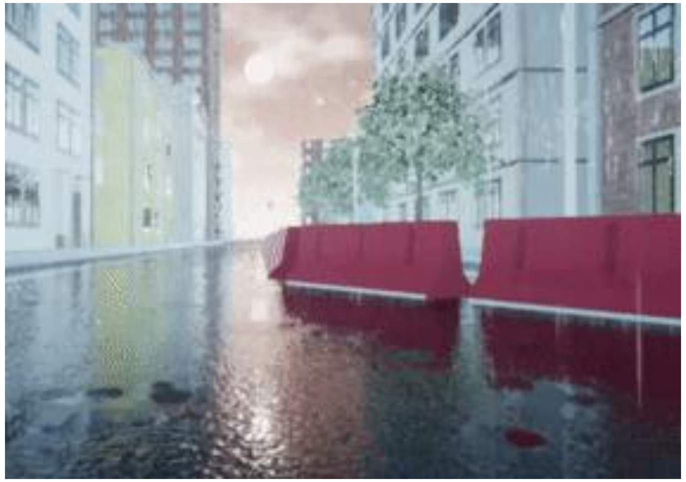
Vehicle lights

Simulation 3D Vehicle with Ground Following

Automated Driving Toolbox™

R2021a

Weather & sun position



Simulation 3D Scene Configuration

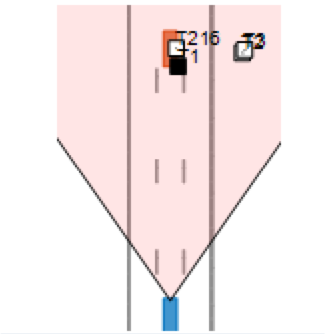
Automated Driving Toolbox™

R2021a

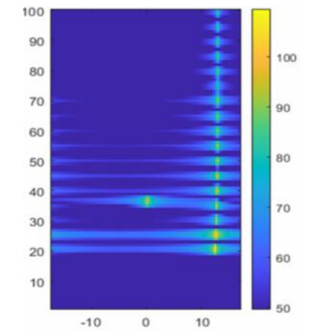
Simulate sensors for automated driving applications

Cuboid Sensors

Radar Tracks

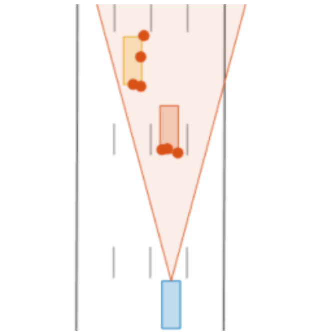


Radar IQ Signals

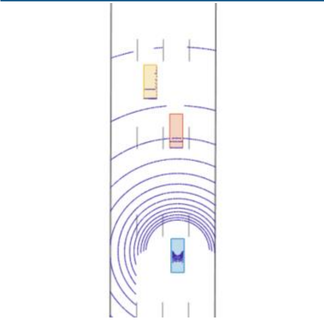


Cuboid & Unreal Engine

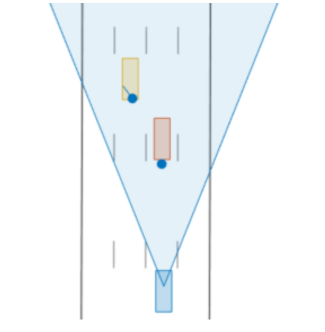
Radar Detections



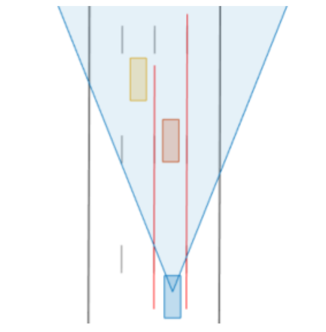
Lidar



Vision Detections



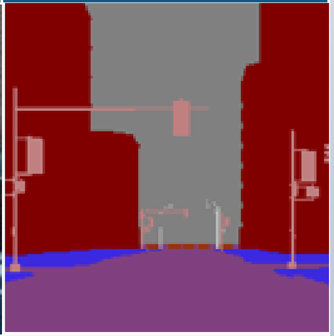
Lane Detections



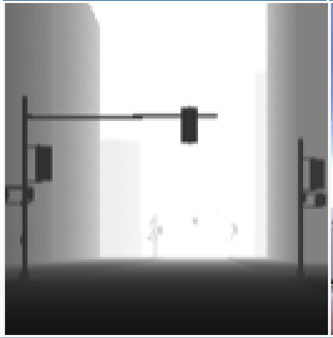
Unreal Engine Sensors

Monocular Camera

Semantic Segmentation



Depth



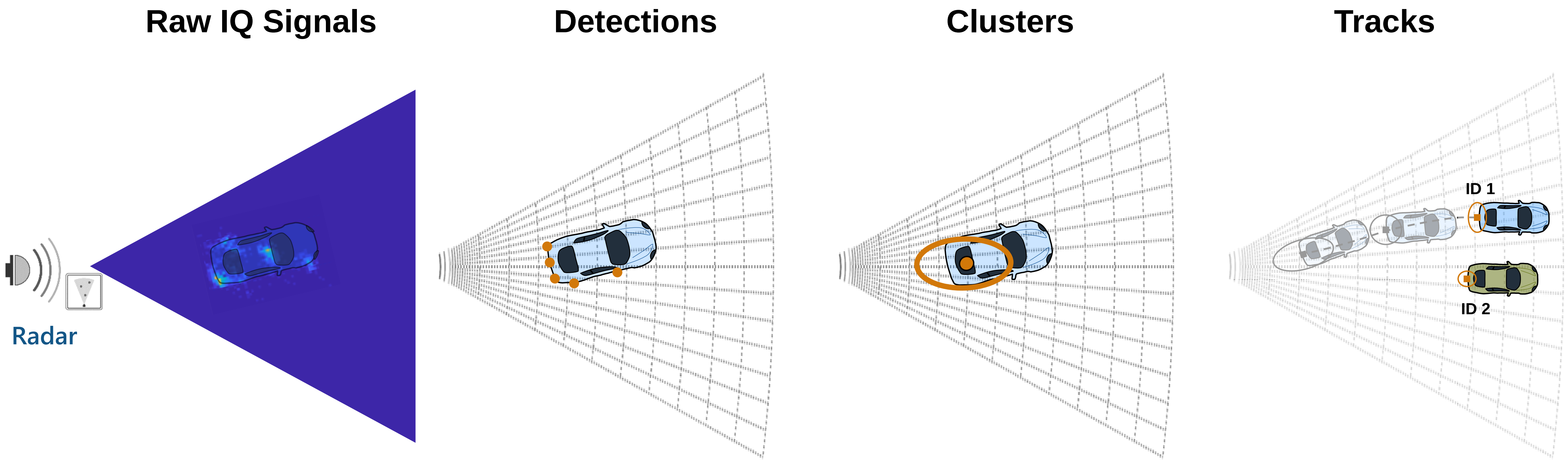
Fisheye Camera

Positional Sensors

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

Commonly used tools: Automated Driving Toolbox™, Radar Toolbox, Navigation Toolbox™

Simulate radar sensors at waveform and measurement levels

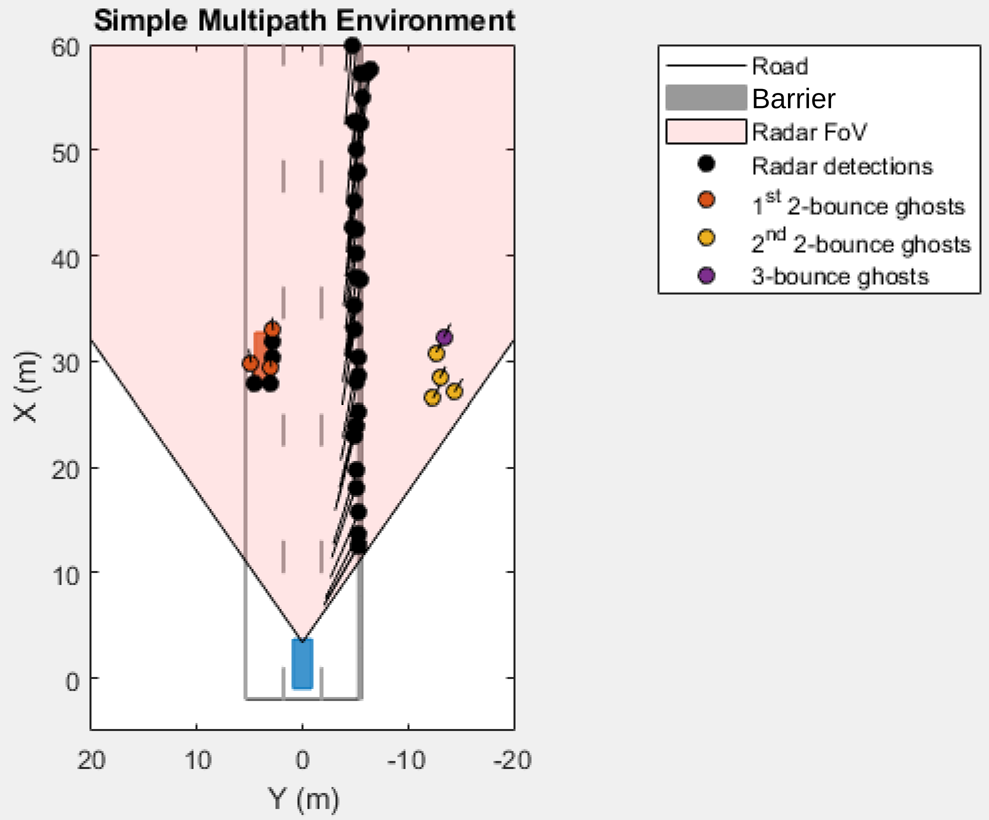


Waveform-level Model	Measurement-level Model
Radar Transceiver *Radar Toolbox*	Driving Radar Data Generator *Automated Driving Toolbox™, Radar Toolbox*

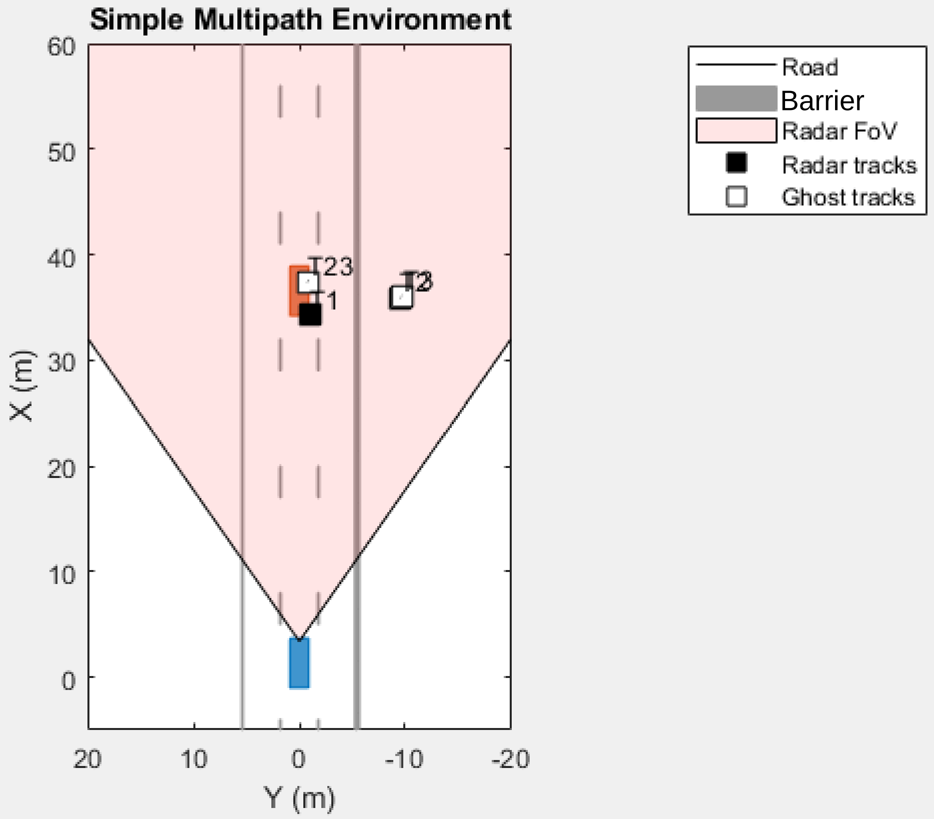
R2021a

Explore example of simulating radar multipath propagation effects

Radar Detection Sensor Model



Radar Tracks Sensor Model



Simulate Radar Ghosts due to Multipath Return

Automated Driving Toolbox™, Radar Toolbox

R2021a

Label recorded sensor data

Camera data

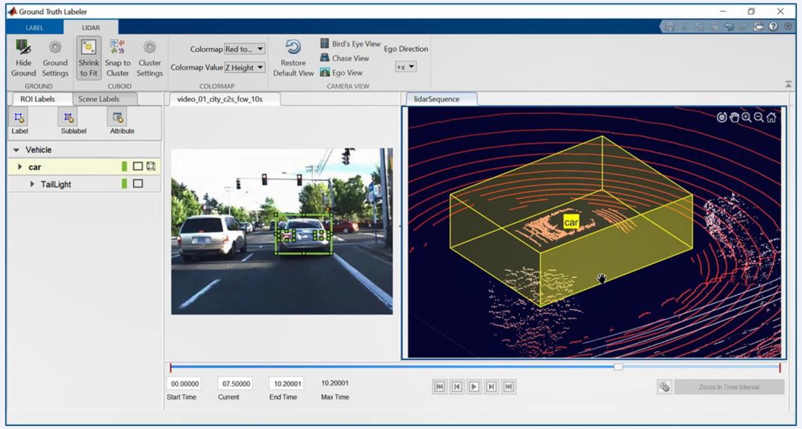
Lidar data

Custom data

Custom automation algorithms

Label Sensor Data

Ground Truth Labeler App



Automation Algorithms

Vehicles, people, lane boundaries, point tracker, temporal interpolator

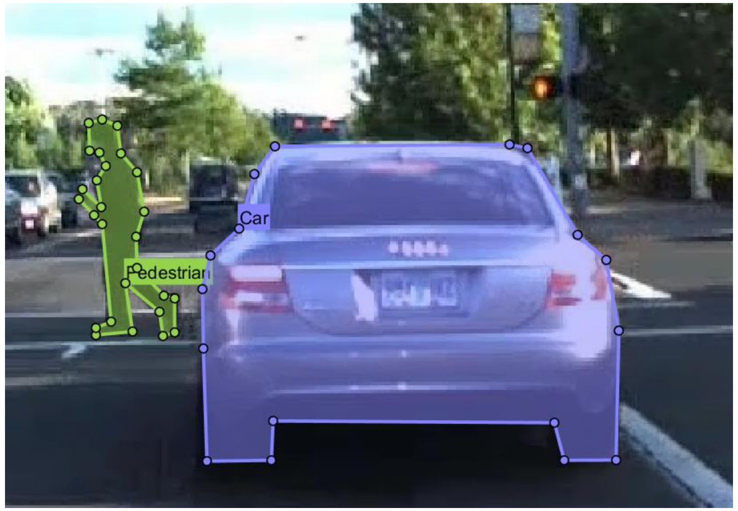
Labels:

- Regions of Interest: cuboid, rectangular, polygon, polyline
- Pixels (semantic segmentation)
- Sublabels
- Attributes
- Scenes (events)

Custom user interfaces

Learn about new features for labeling sensor data

Label polygon regions of interest

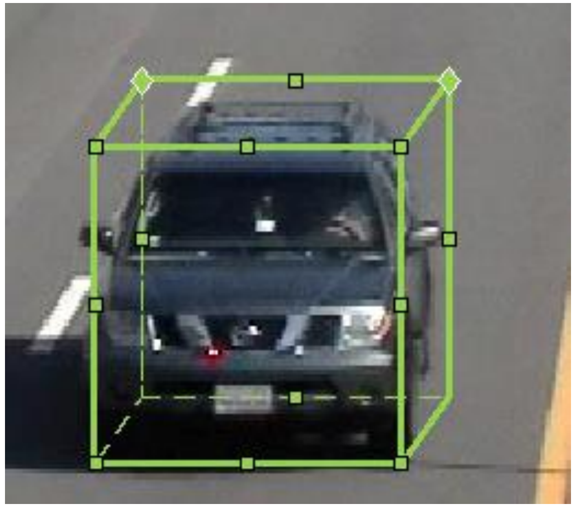


[Label Objects Using Polygons](#)

Automated Driving Toolbox™

R2021a

Label projected cuboids

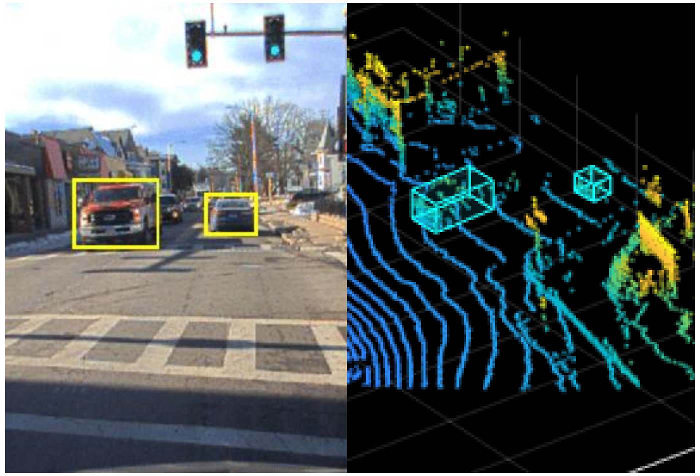


[Ground Truth Labeler](#)

Automated Driving Toolbox™

R2020b

Automate labeling for camera and lidar



[Automate Ground Truth Labeling Across Multiple Signals](#)

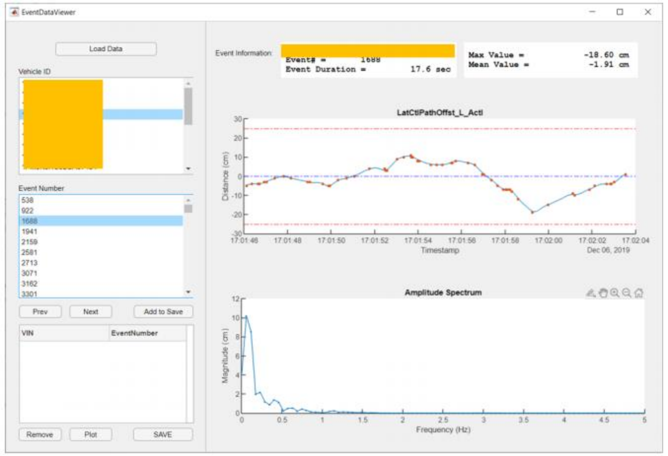
Automated Driving Toolbox™

Lidar Toolbox™

R2021a

Partner with MathWorks to extend virtual development workflows

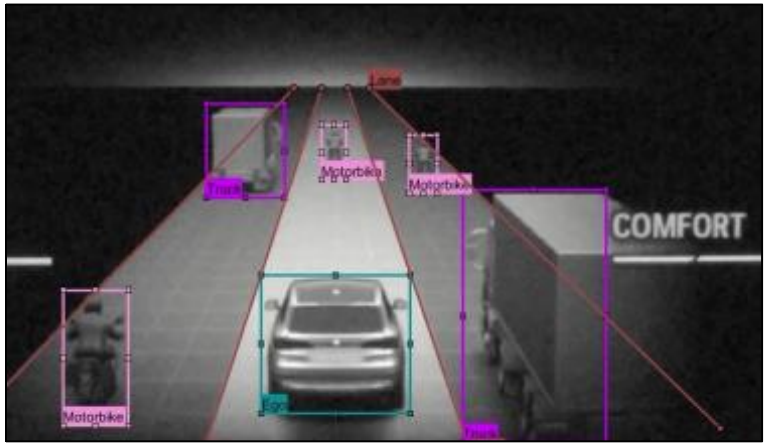
Ford identifies events in recorded data



[Using MATLAB on Apache Spark for ADAS Feature Usage Analysis and Scenario Generation](#)

MathWorks Automotive Engineer Conference 2020

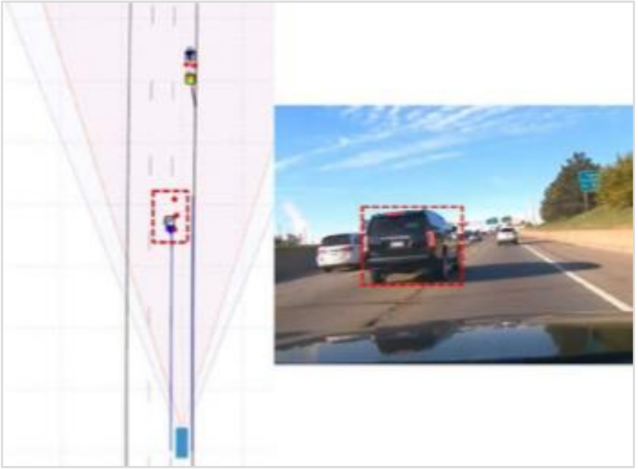
BMW automates labeling display images



[Automated Verification of Automotive Infotainment](#)

MathWorks Automotive Conference 2020 – Europe

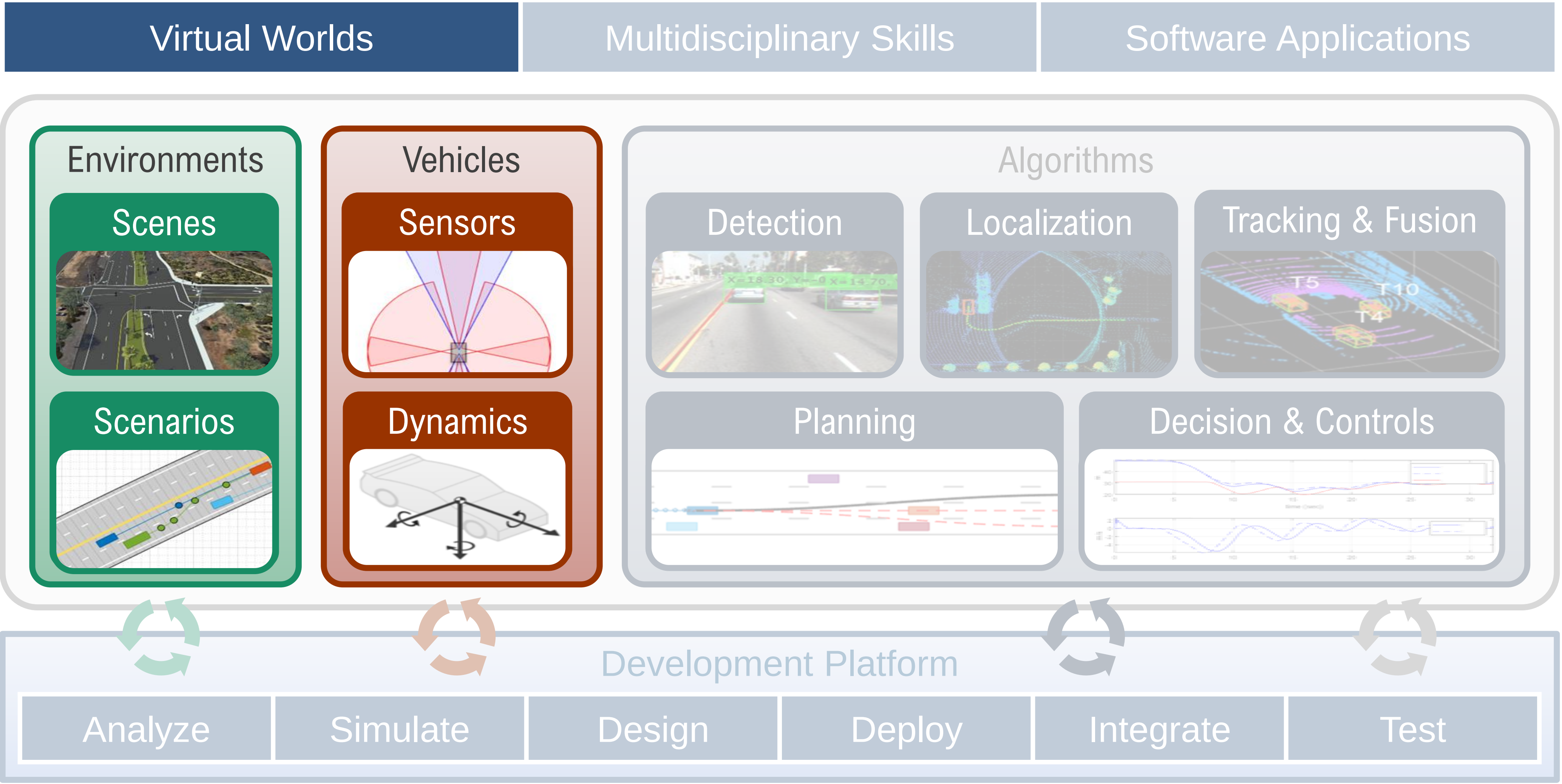
GM generate scenarios from recorded data



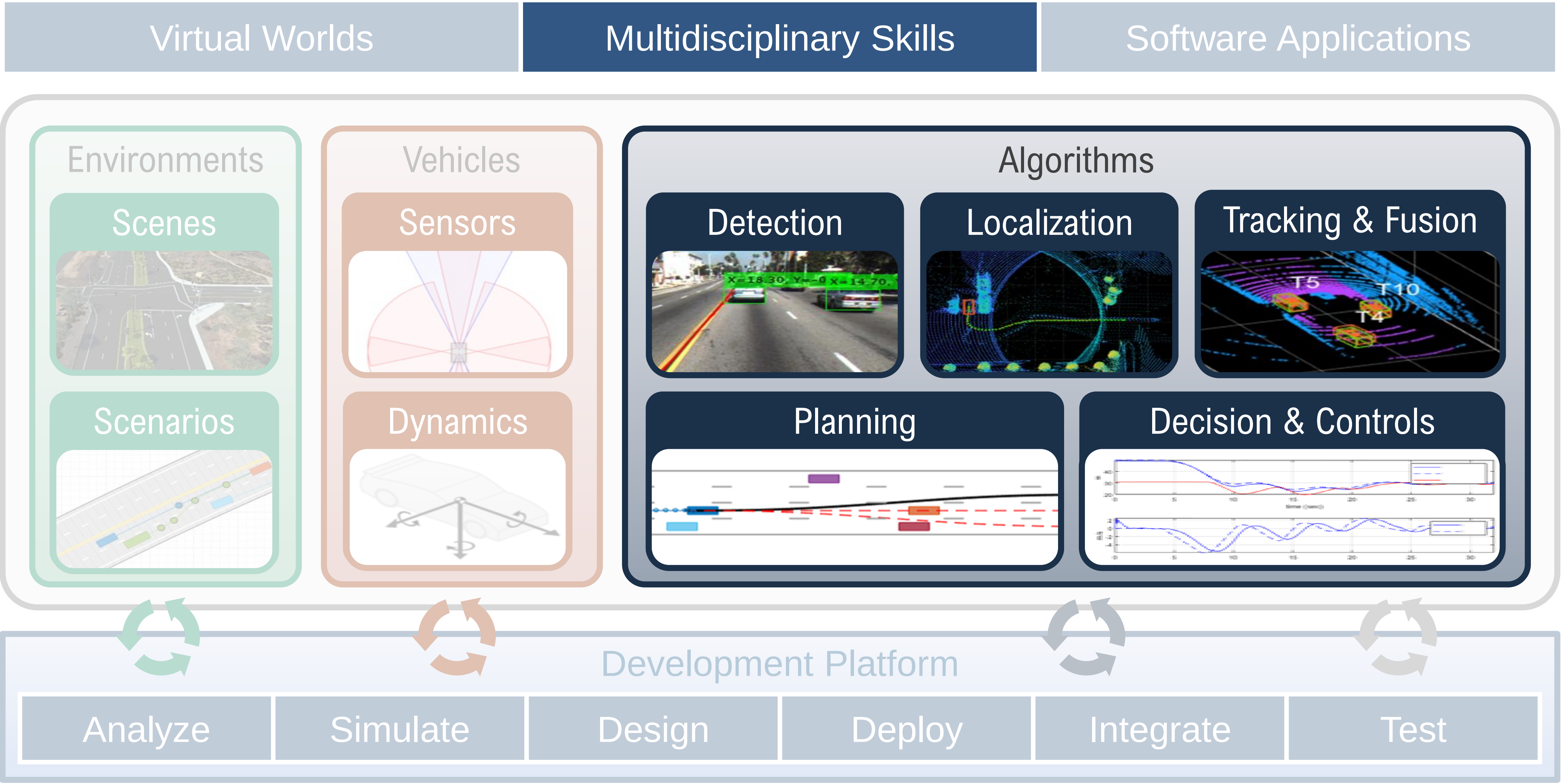
[Creating Driving Scenarios from Recorded Vehicle Data for Validating Lane Centering Systems](#)

MathWorks Automotive Conference 2020 – North America

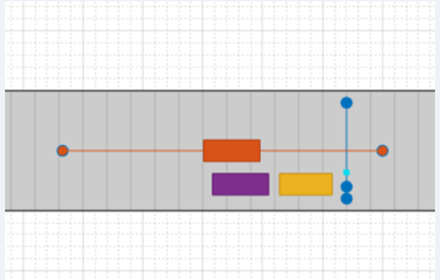
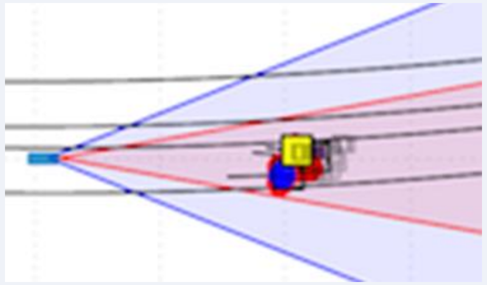
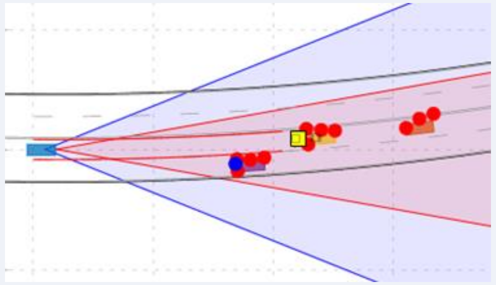
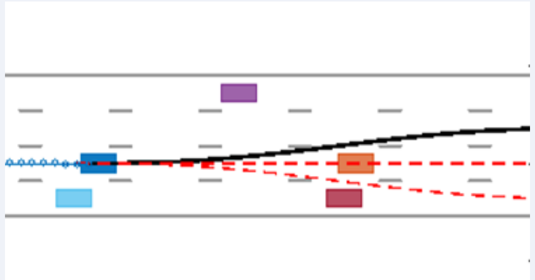
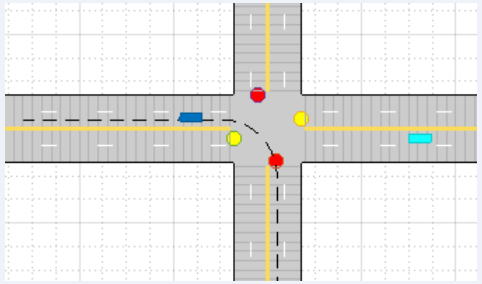
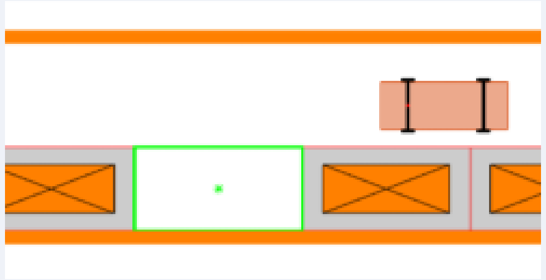
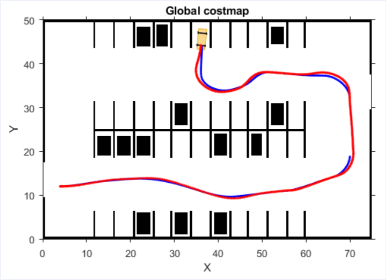
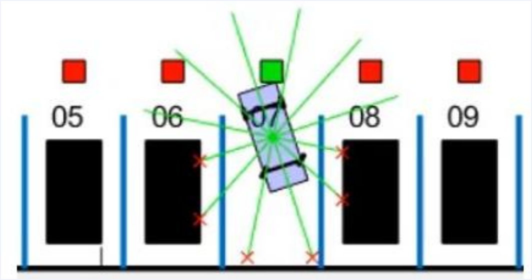
Develop virtual worlds for automated driving systems



Develop multidisciplinary skills for automated driving



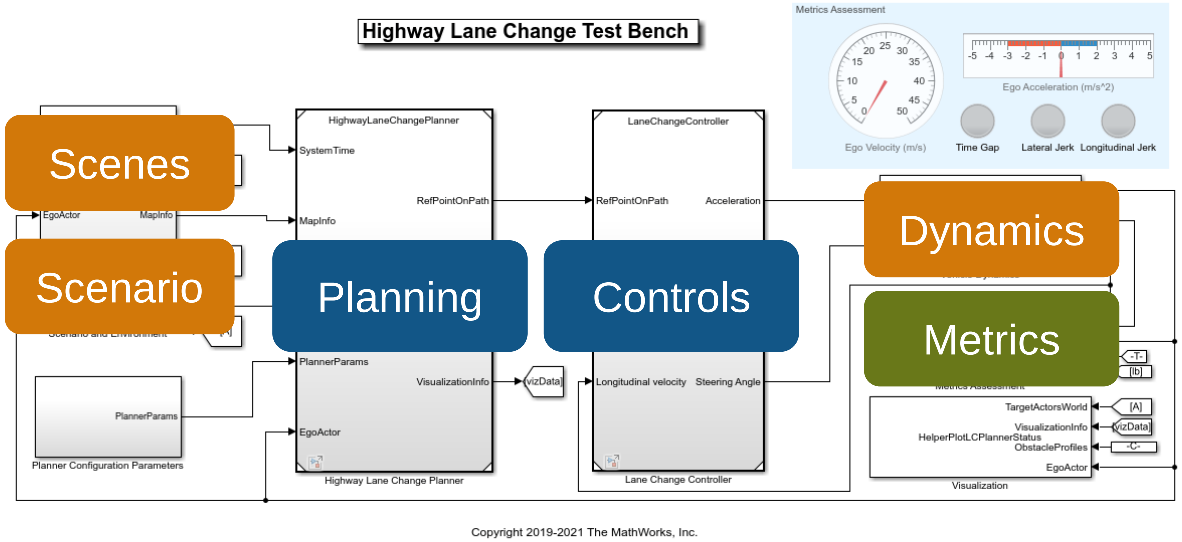
Design planning and control algorithms for automated driving

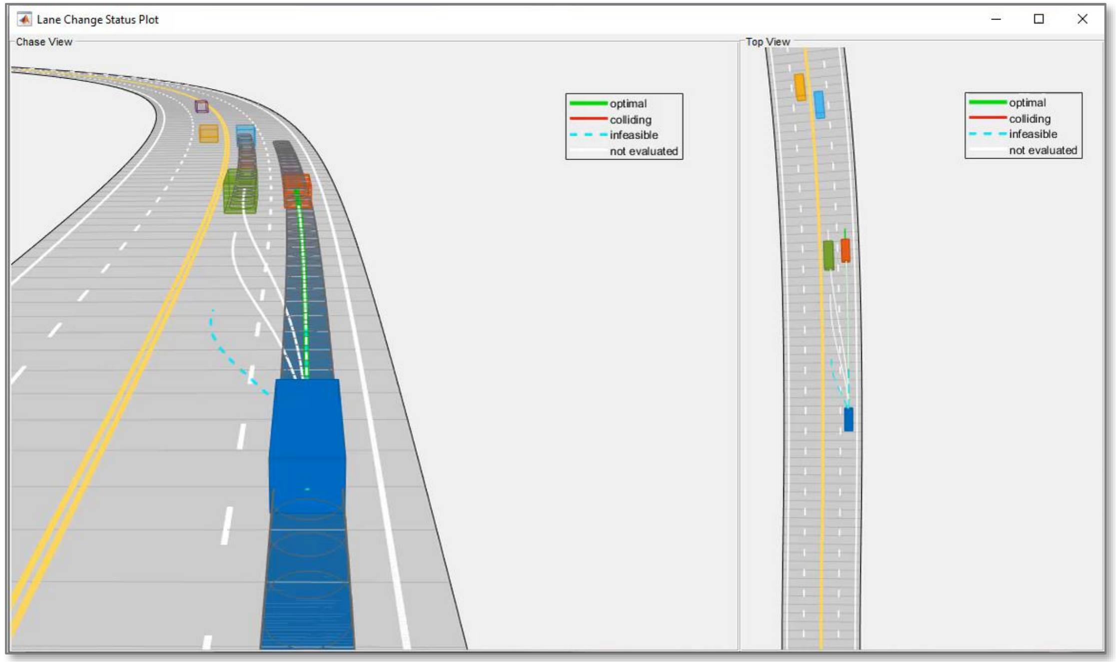
Emergency Braking	Adaptive Cruise Control	Lane Following	Lane Change
			
Traffic Light Negotiation	**Parallel Parking**	**Parking Lot**	**Reinforcement Learning**
			

Commonly used tools: Automated Driving Toolbox, Model Predictive Control Toolbox, Stateflow, Navigation Toolbox, Reinforcement Learning, Robotics System Toolbox

Explore updated example:

Design planning and controls for highway lane change





- Generates an optimal trajectory in Frenet space
- Implement driving maneuver behavior depending on surrounding traffic conditions
- Collision checking using dynamic capsule-based objects

[Highway Lane Change](#)

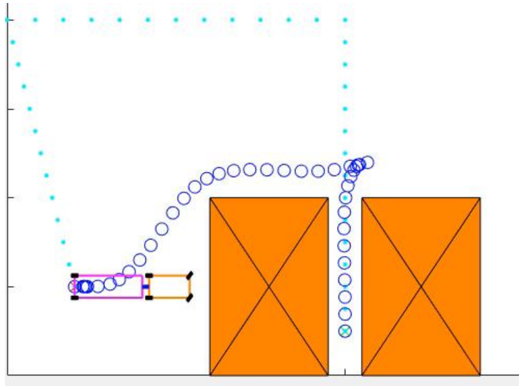
Navigation Toolbox™, Model Predictive Control Toolbox™, Automated Driving Toolbox™

Updated

R2021a

Explore new examples to design planning and controls algorithms

Planning for truck parking

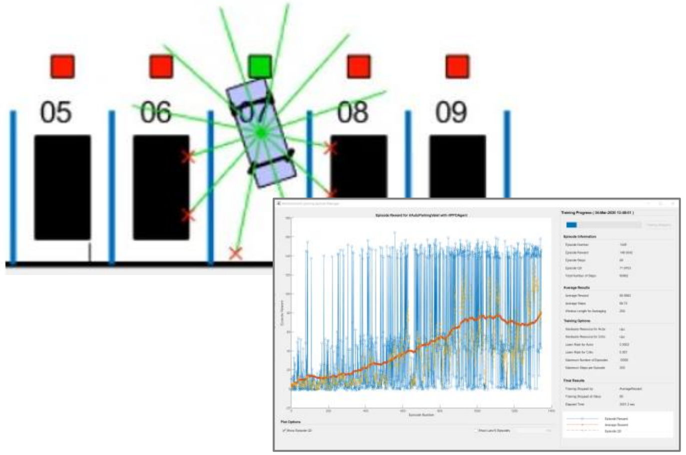


Truck and Trailer Automatic Parking Using Multistage Nonlinear MPC

Model Predictive Control Toolbox
Robotics System Toolbox

R2021a

Parking with reinforcement learning

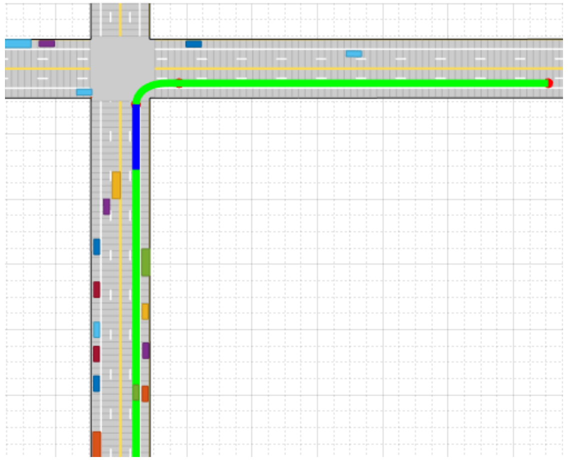


Train PPO Agent for Automatic Parking Valet

Reinforcement Learning Toolbox
Model Predictive Control Toolbox

R2020b

Planning for urban



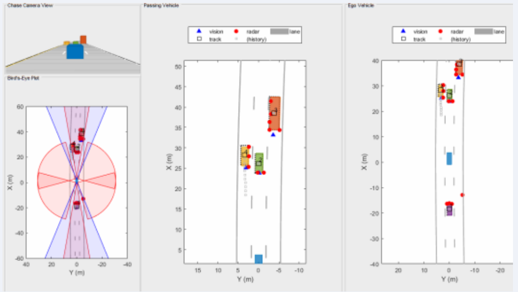
Motion Planning in Urban Environments Using Dynamic Occupancy Grid Map

Automated Driving Toolbox,
Navigation Toolbox,
Sensor Fusion and Tracking Toolbox,

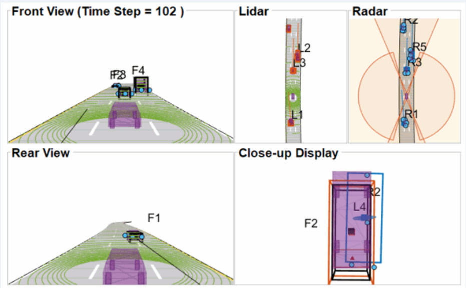
R2021a

Design tracking and fusion algorithms for automated driving

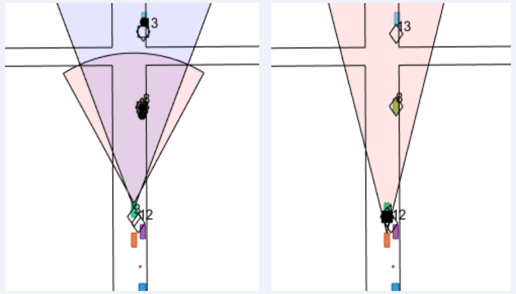
Radar & Vision



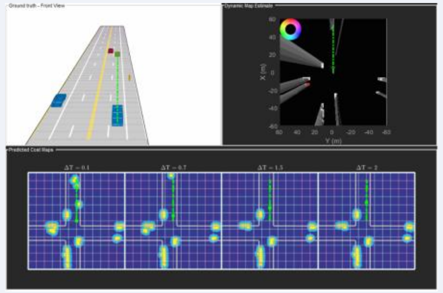
Lidar & Radar



Vehicle to Vehicle

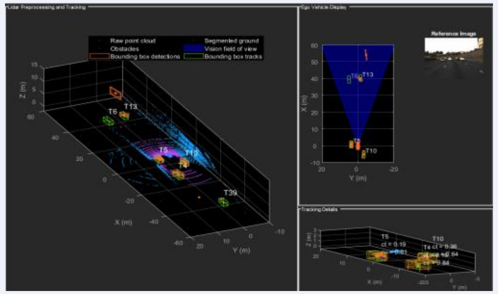


Occupancy Grids

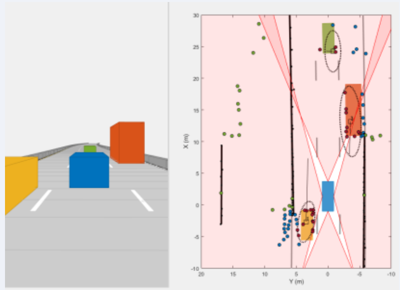


Camera

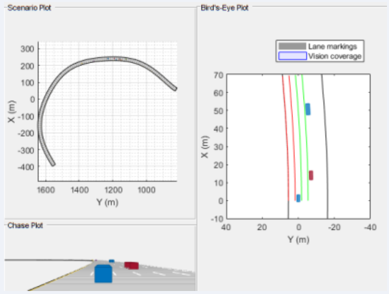
Lidar



Radar with Multipath



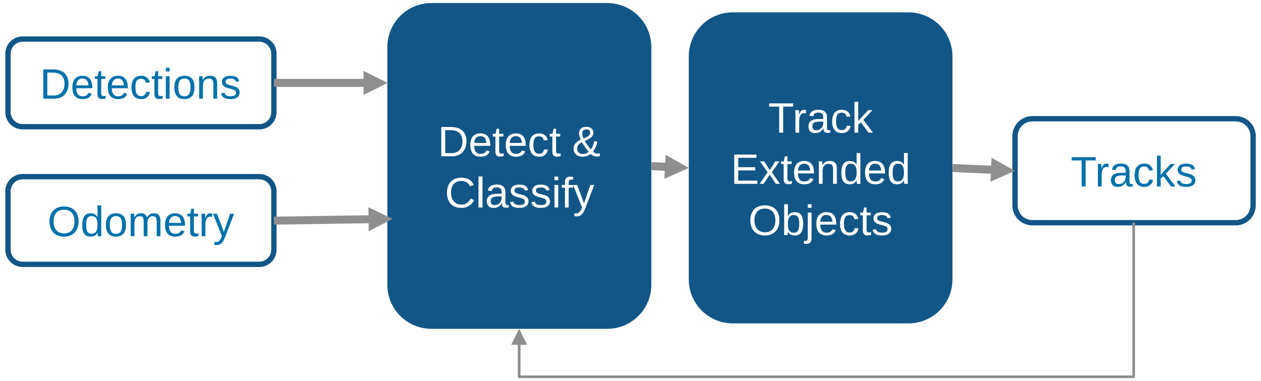
Lane Boundaries



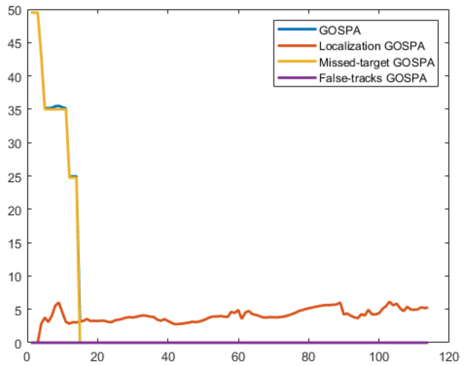
Commonly used tools: Automated Driving Toolbox, Tracking and Fusion Toolbox, Radar Toolbox

Explore new example:

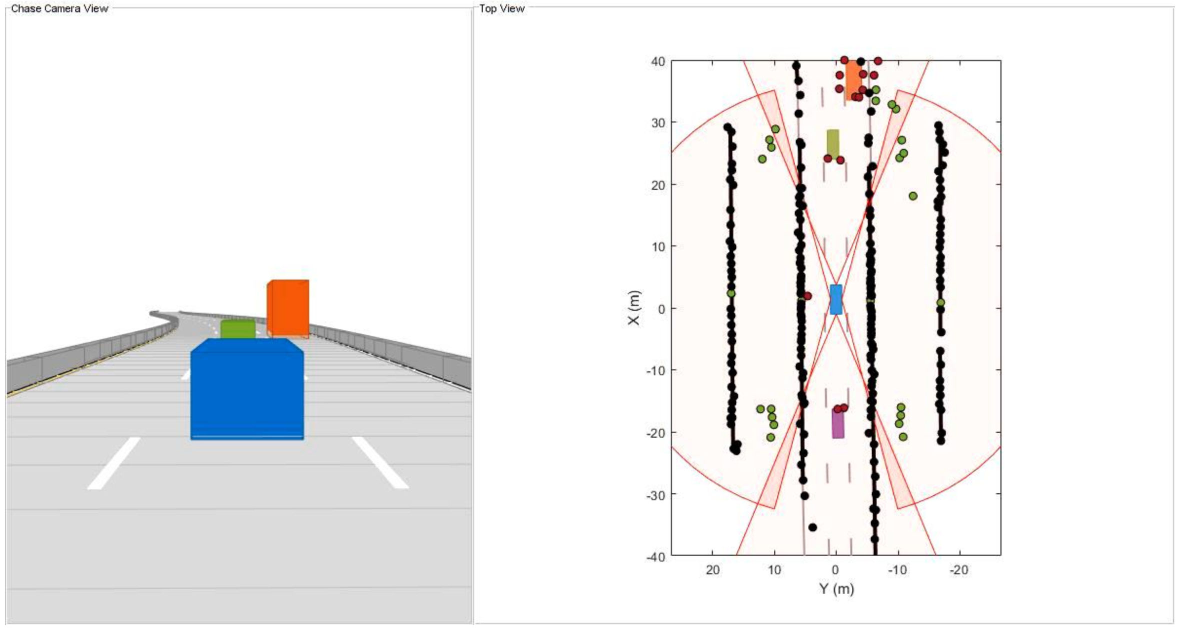
Track vehicles in presence of multipath radar reflections



Classification metrics



Tracker metrics



[Highway Vehicle Tracking with Multipath Radar Reflections]

Automated Driving Toolbox™, Sensor Fusion and Tracking Toolbox™, Radar Toolbox™

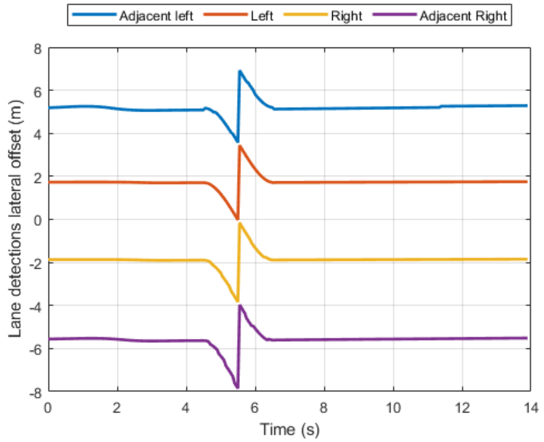
R2021a

Explore new example:

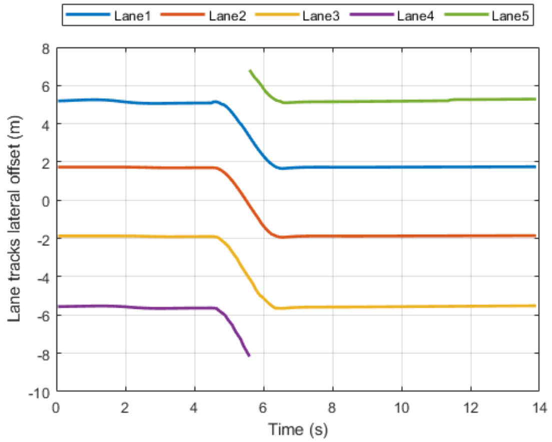
Track multiple lane boundaries

Parametric coefficients

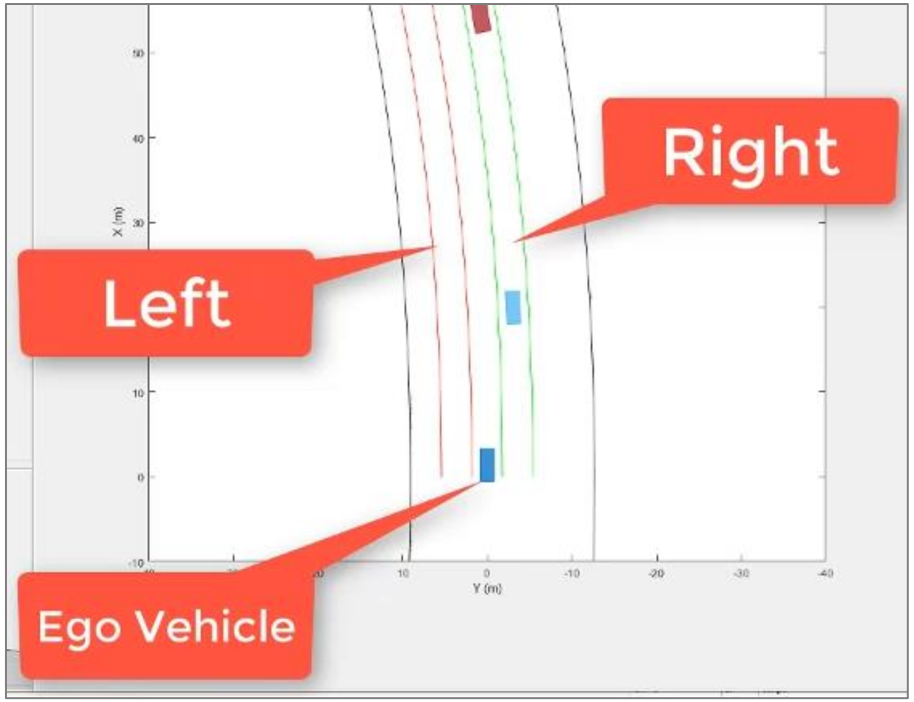
Parametric coefficients



Lane Detections



Lane Tracks



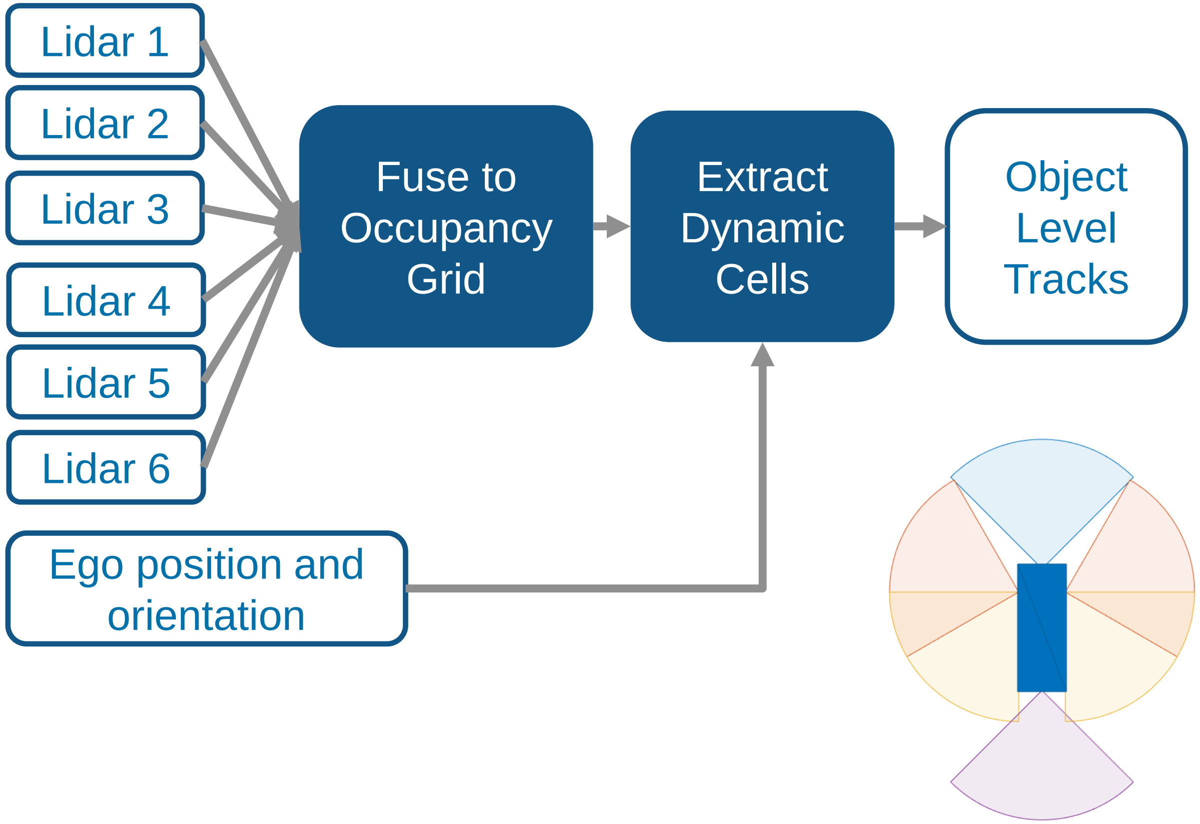
[Track Multiple Lane Boundaries with a Global Nearest Neighbor Tracker]

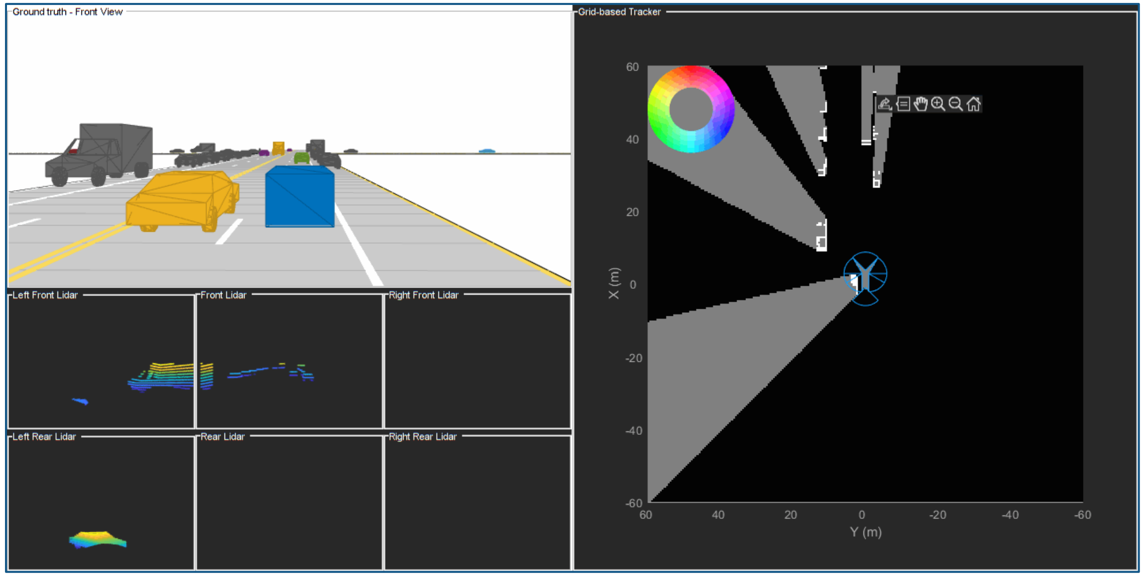
Automated Driving Toolbox™, Sensor Fusion and Tracking Toolbox™

R2020b

Explore new example:

Track objects in urban environment with grid-based tracking



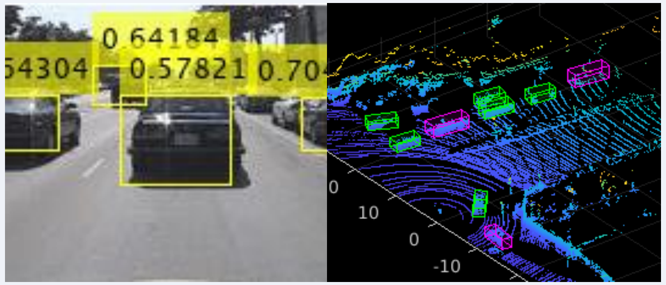
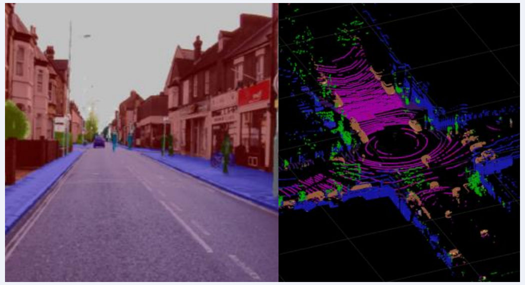
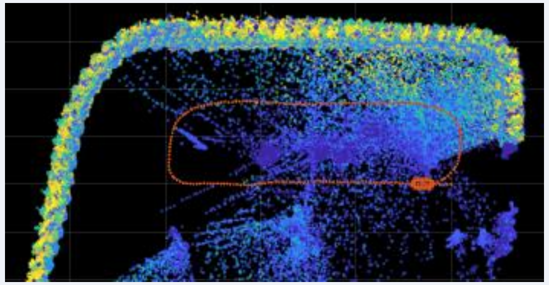
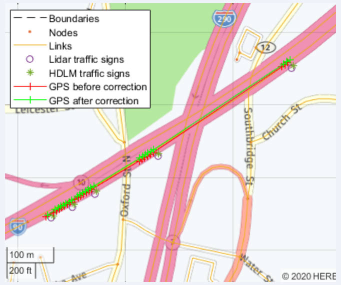
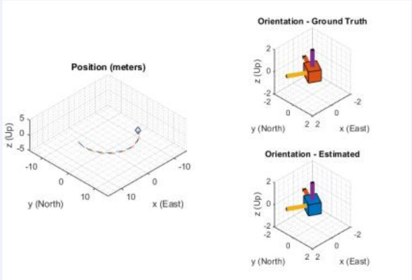


Grid-based Tracking in Urban Environments Using Multiple Lidars

Automated Driving Toolbox™, Sensor Fusion and Tracking Toolbox™

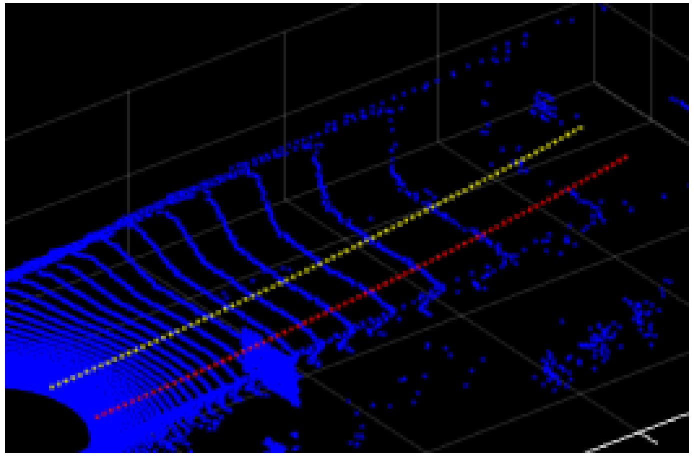
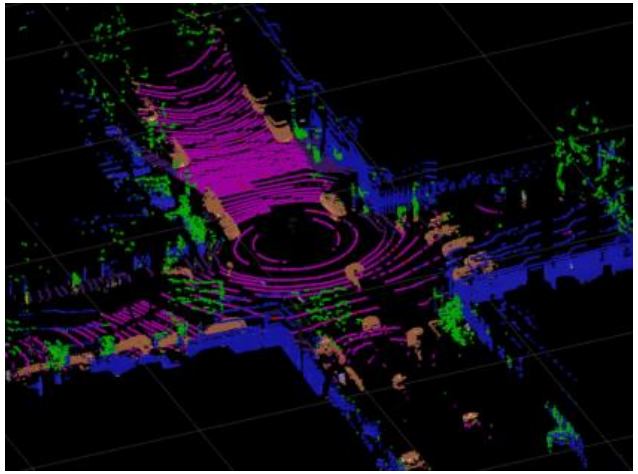
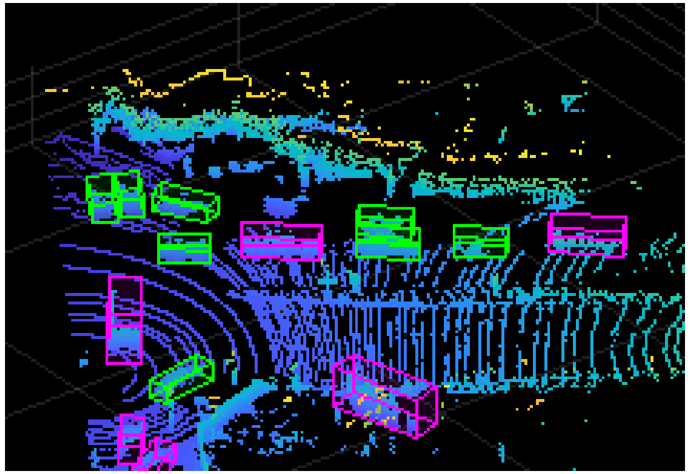
R2020b

Design detection and localization algorithms for automated driving

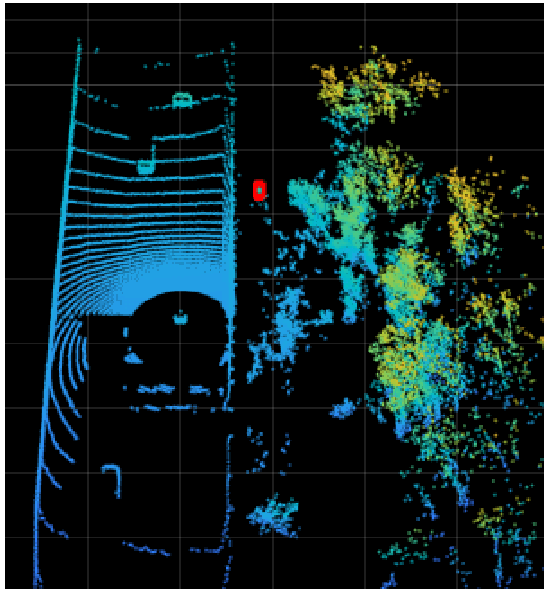
Lanes	Objects	Semantic Segmentation
		
SLAM	**Maps**	**Inertial Fusion**
		

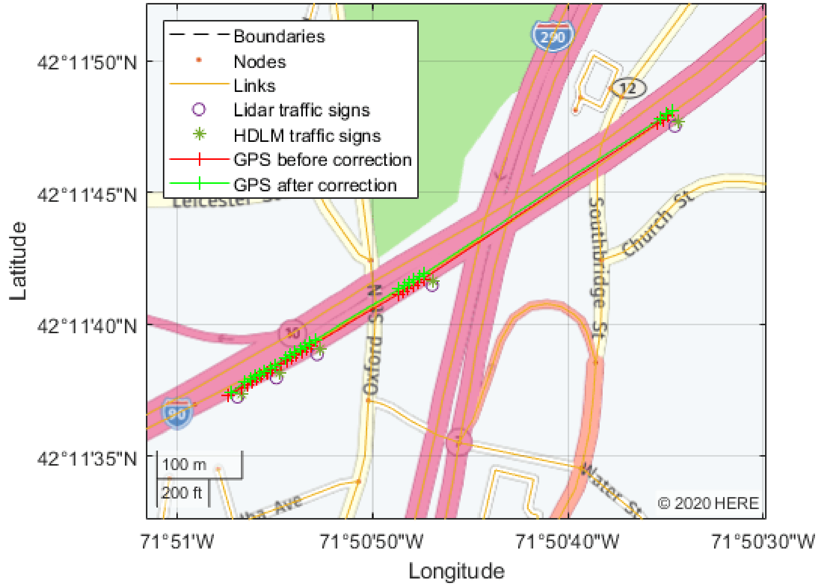
Commonly used tools: Automated Driving Toolbox, Computer Vision, Lidar Toolbox, Radar Toolbox, Deep Learning Toolbox, Navigation Toolbox

Explore new examples to design lidar detection algorithms

Lanes	Semantic segmentation	PointPillars
		
Lane Detection in 3-D Lidar Point Cloud *Lidar ToolboxTM*	Lidar Point Cloud Semantic Segmentation Using SqueezeSegV2 Deep Learning Network *Lidar ToolboxTM,* *Deep Learning ToolboxTM*	Lidar 3-D Object Detection Using PointPillars Deep Learning *Lidar ToolboxTM,* *Deep Learning ToolboxTM*
R2021a	Updated R2021a	Updated R2021a

Explore example of designing localization algorithms with map data





- Read traffic sign information from HERE HD Live Map
- Match signs detected by the onboard sensors with signs stored map data
- Improve localization accuracy by combining GPS measurements with map data

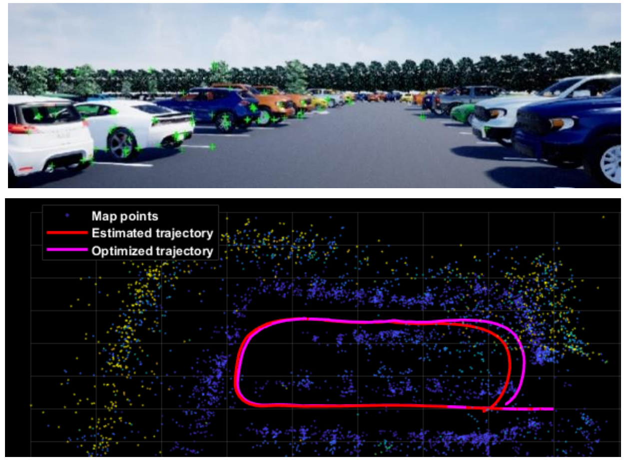
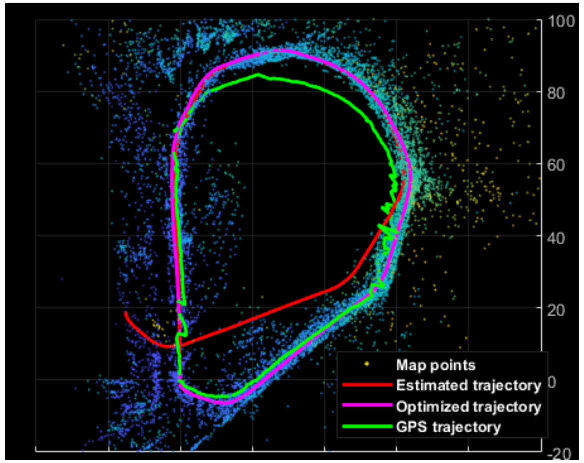
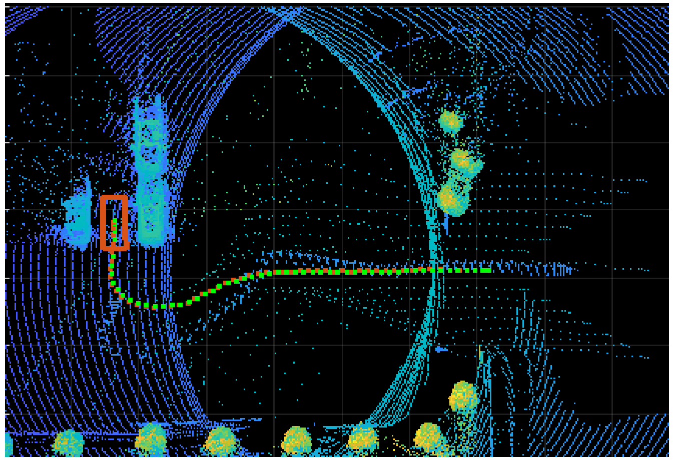
[Localization Correction Using Traffic Sign Data from HERE HD Maps]

Automated Driving Toolbox™

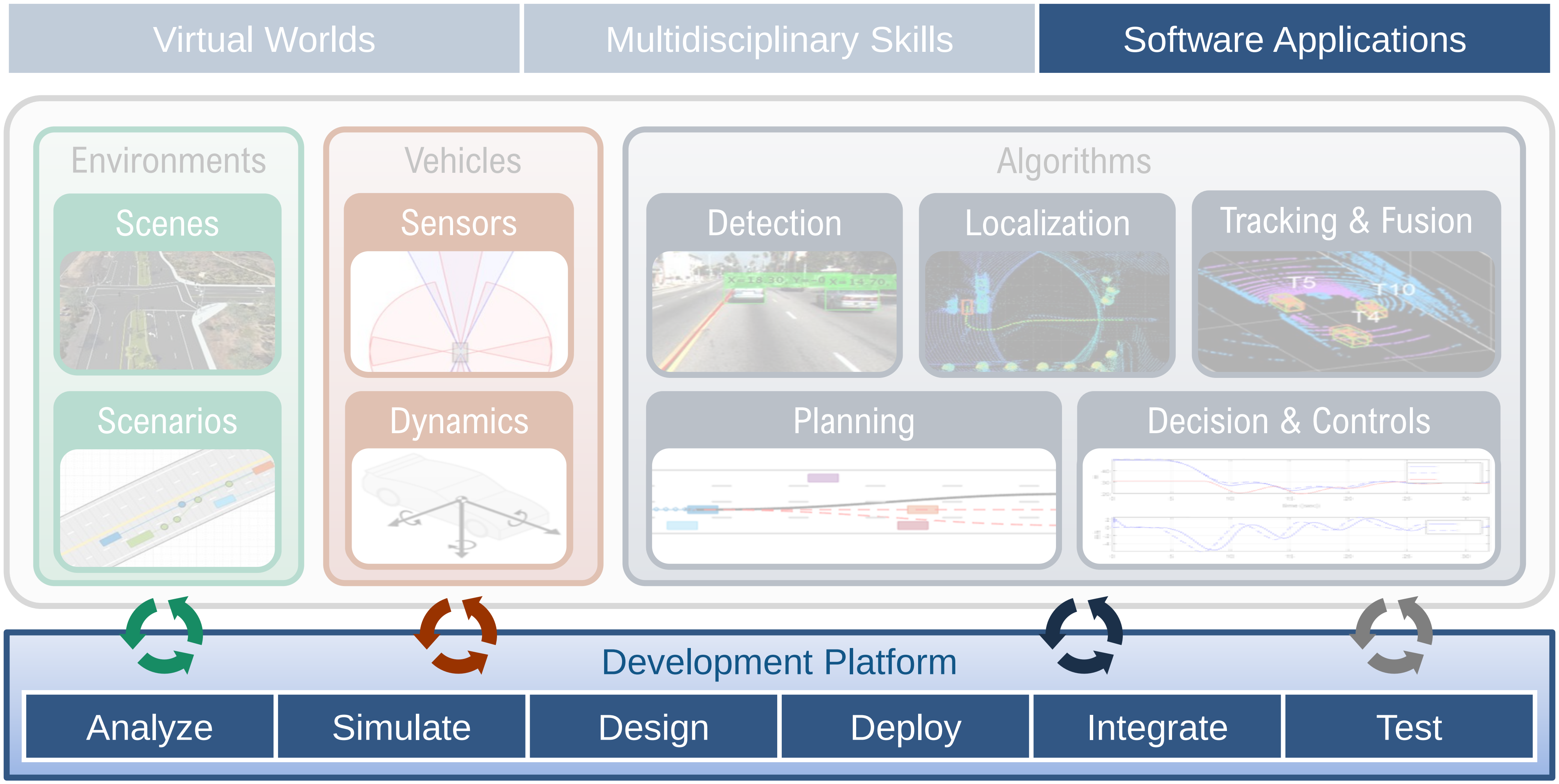
R2021a

Explore new examples to design SLAM algorithms

SLAM = Simultaneous Localization and Mapping

Monocular camera	Stereo camera	Lidar
		
Develop Visual SLAM Algorithm Using Unreal Engine Simulation *Automated Driving Toolbox™* *Computer Vision Toolbox™* *Navigation Toolbox™*	Stereo Visual Simultaneous Localization and Mapping *Computer Vision Toolbox™*	Design Lidar SLAM Algorithm using 3D Simulation Environment *Automated Driving Toolbox™* *Computer Vision Toolbox™* *Navigation Toolbox™*
R2020b	R2021a	R2020b

Develop software applications for automated driving

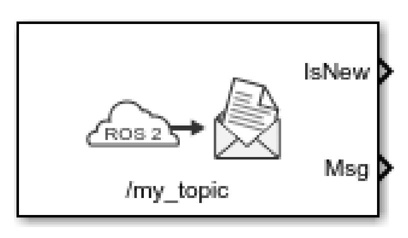


Develop software applications for automated driving

Code

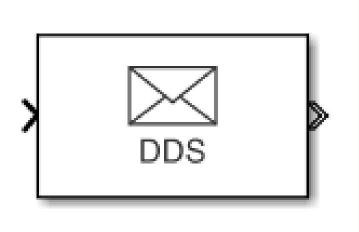
C | C++ | GPU | HDL

ROS / ROS 2.0

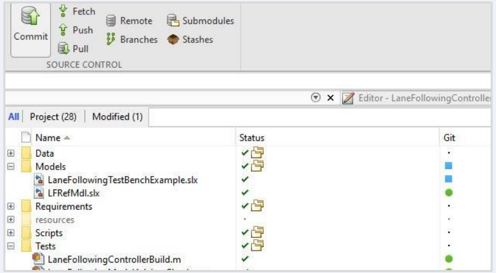


AUTOSAR

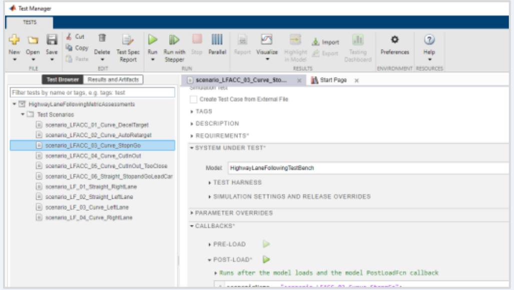
DDS



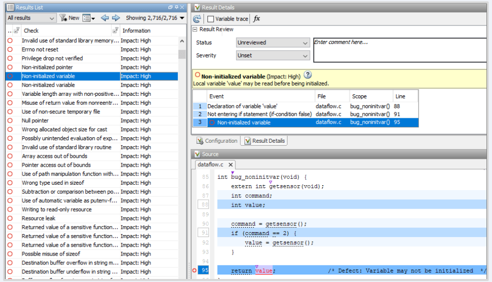
Continuous Integration



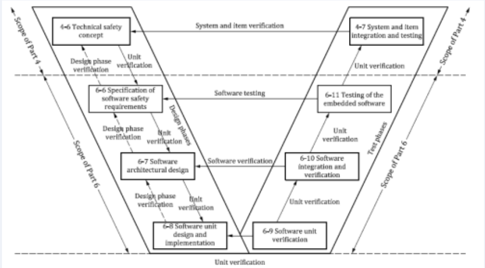
Automated Testing



Code Analysis



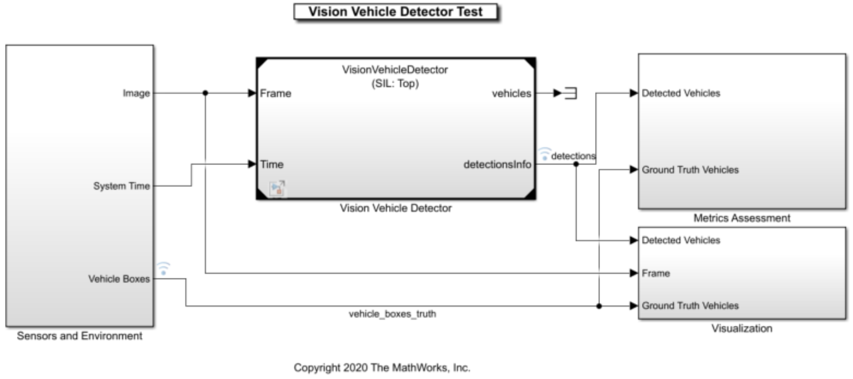
ISO 26262

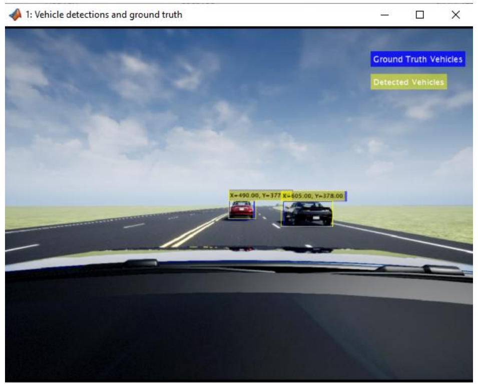


Commonly used tools: MATLAB Coder, Embedded Coder, GPU Coder, HDL Coder,
ROS Toolbox, AUTOSAR Blockset, DDS Blockset,
Simulink Test, Simulink Coverage, Polyspace, IEC Certification Kit,

Explore new example:

Generate C/C++ or GPU code from vision detectors in Simulink

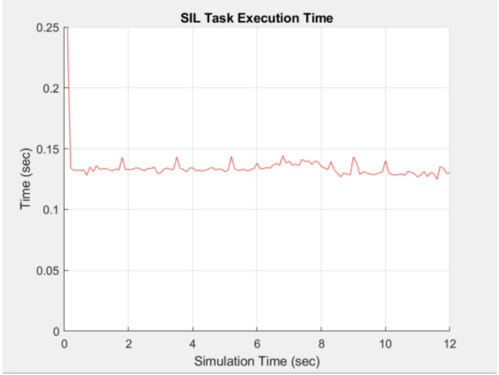


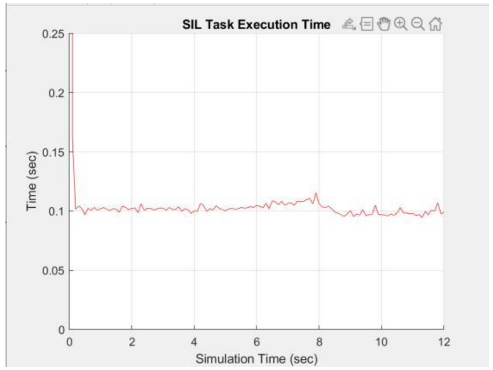


- Generate code, verify functionality, and measure execution time with Software-In-the Loop (SIL)

CPU: Intel® Xeon® @ 3.60GHz, **GPU:** Quadro K620

YOLOv2 CPU - MKLDNN	YOLOv2 GPU - cuDNN	YOLOv2 GPU - tensorRT





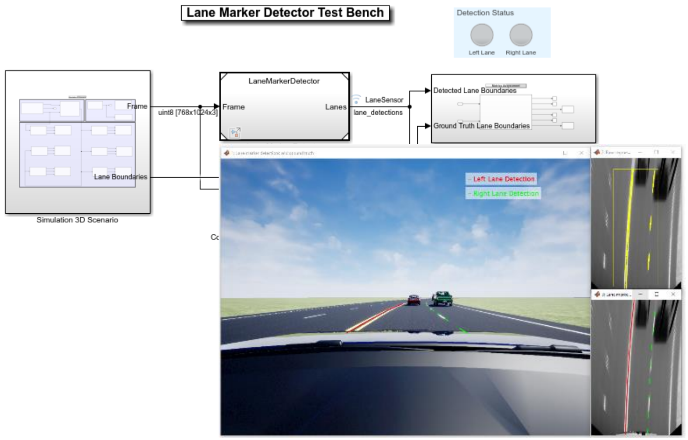
[Generate Code for Vision Vehicle Detector]

Automated Driving Toolbox™, Embedded Coder®, Computer Vision Toolbox

R2021a

Explore new examples of generating C/C++ code

Deploy lane detection to C/C++

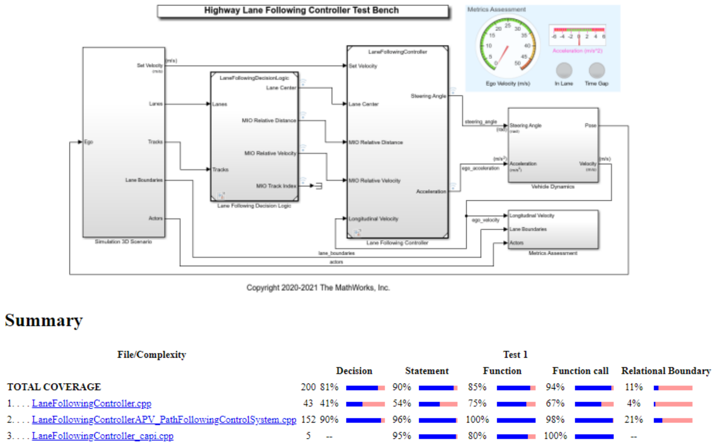


[Generate Code for Lane Marker Detector]

Automated Driving Toolbox™
Embedded Coder

R2020b

Deploy controls to C/C++

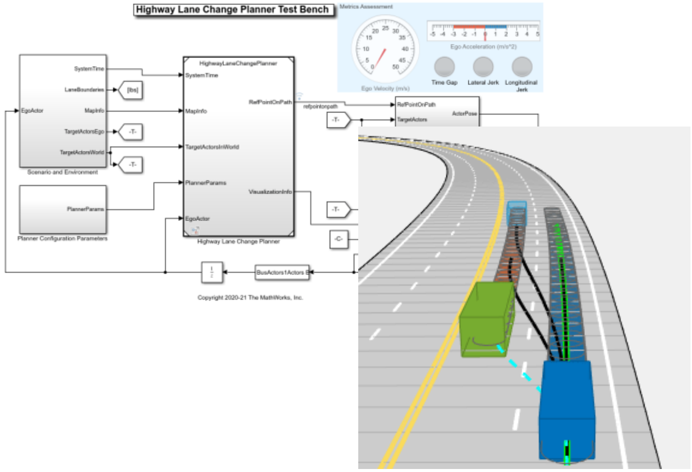


[Generate Code for Highway Lane Following Controller]

Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder

R2021a

Deploy planning to C/C++



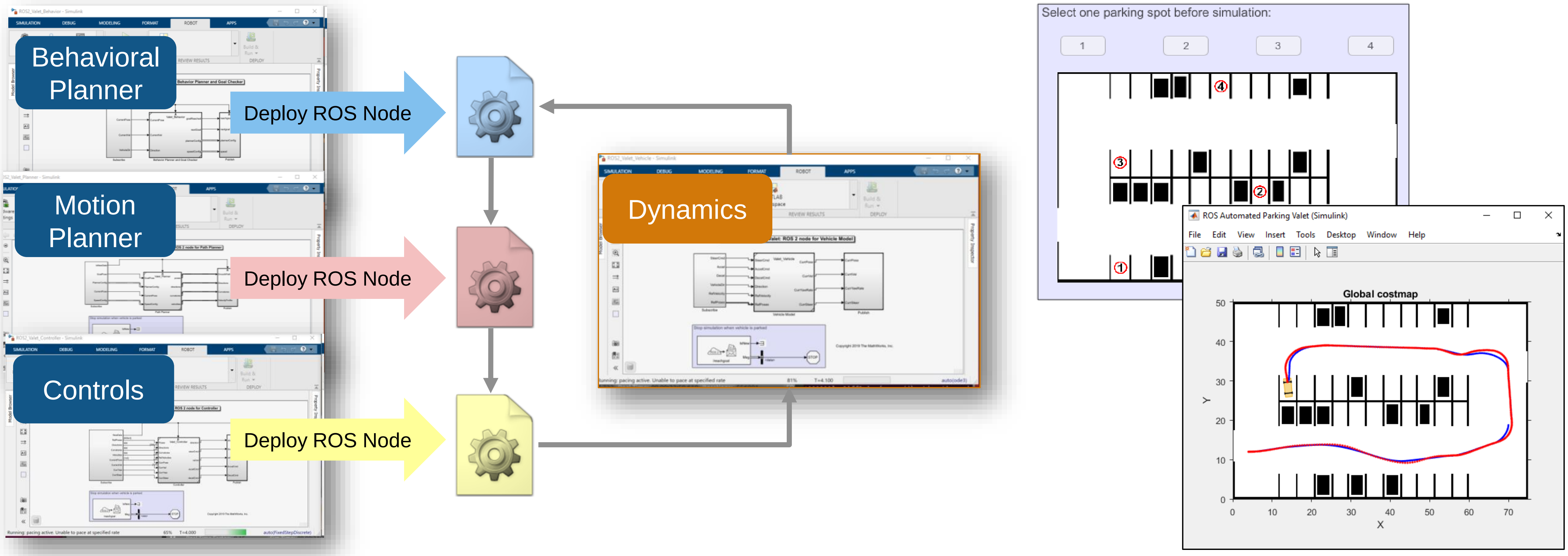
[Generate Code for Highway Lane Change Planner]

Automated Driving Toolbox™
Navigation Toolbox™
Embedded Coder

R2021a

Explore new example:

Deploy parking valet planning and controls to ROS / ROS 2.0



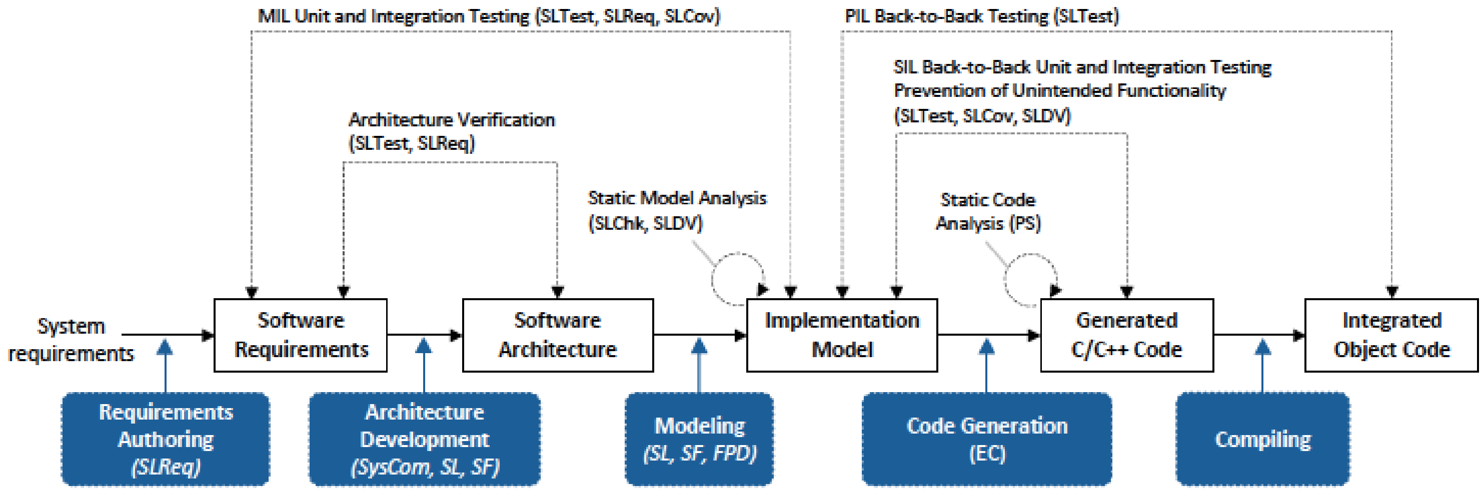
[Automated Parking Valet with ROS in Simulink]

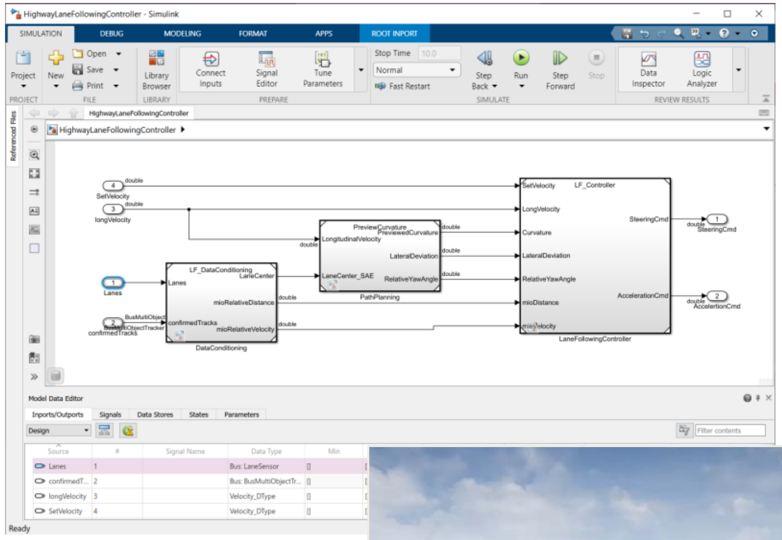
[Automated Parking Valet with ROS 2 in Simulink]

ROS Toolbox, Embedded Coder®, Automated Driving Toolbox™, Model Predictive Control Toolbox™

R2020b

Explore new example:
ISO26262 for decision and controls





- Architect system and software designs
- Trace requirements, architecture, design, and verification artifacts
- Perform static and dynamic verification at model and code level

[Highway Lane Following: A Model-Based Design Example for ISO 26262:2018]

IEC Certification Kit, Automated Driving Toolbox™, System Composer™, Embedded Coder®

Simulink Requirements™, Simulink Coverage™, Simulink Test™, Polyspace Bug Finder™

R2021a

Partner with MathWorks to adopt algorithm development workflows

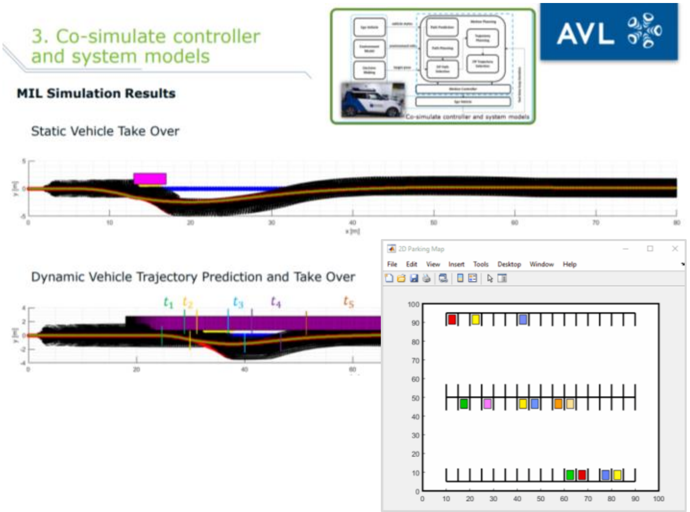
Hitachi Automotive develops controls

"The generated code for the QP solver was extremely efficient, so there was no need for us to explore other solvers."

Hitachi Automotive Systems Develops a Model Predictive Controller for Adaptive Cruise Control with Model-Based Design

User Story – 2020

AVL develops planning & controls



Advantages of Level 2+ Advanced Driver Assistance Application Prototyping Using Model-Based Design

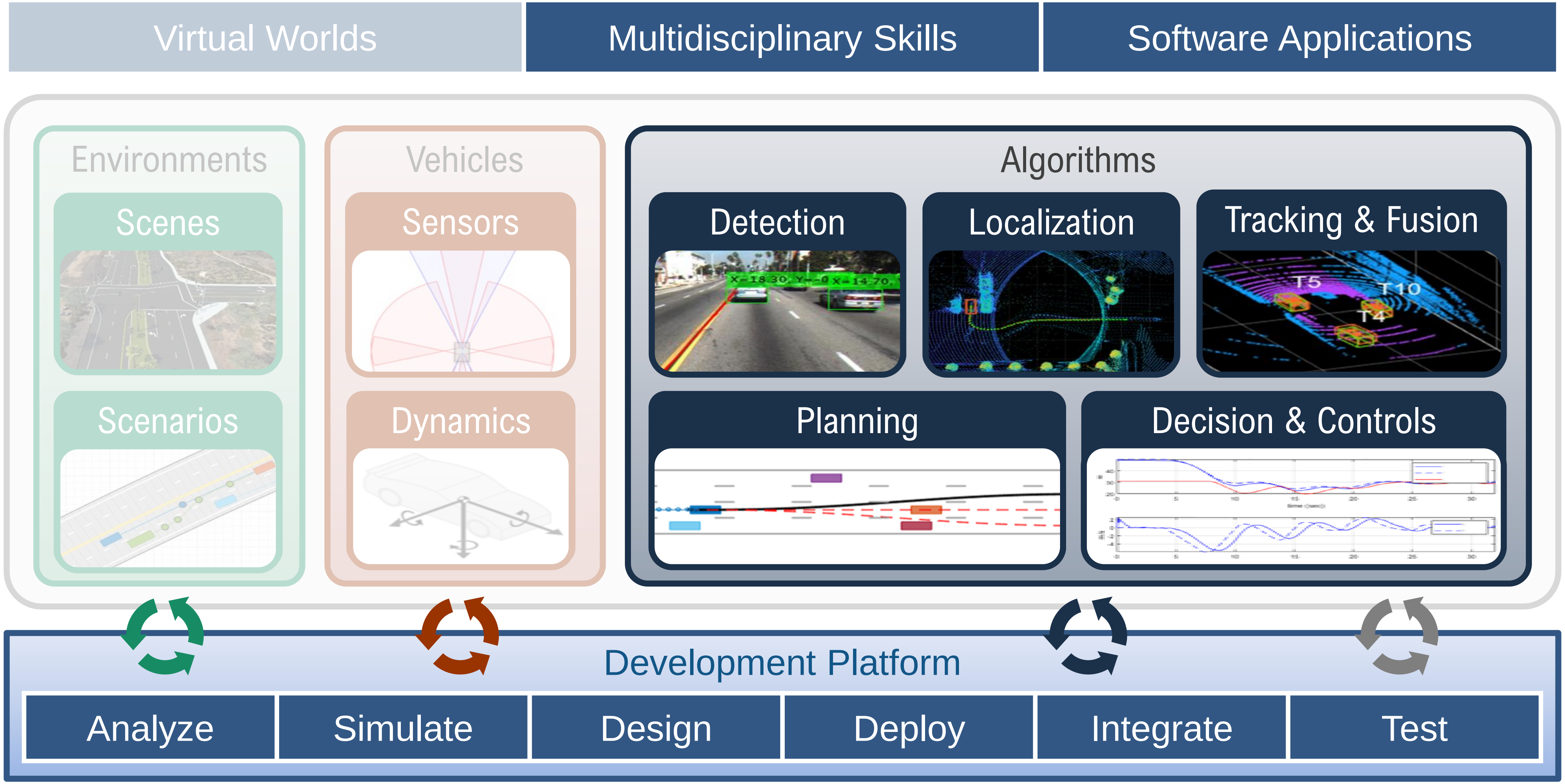
MathWorks Automotive Conference 2020 – Europe

Nippon Sharyo develops sensor fusion

Sensor fusion development for large heavy-duty automatic transport vehicles

MathWorks Expo 2020 – Japan

Develop multidisciplinary skills for automated driving



Develop Automated Driving Systems

with MATLAB, Simulink, and RoadRunner