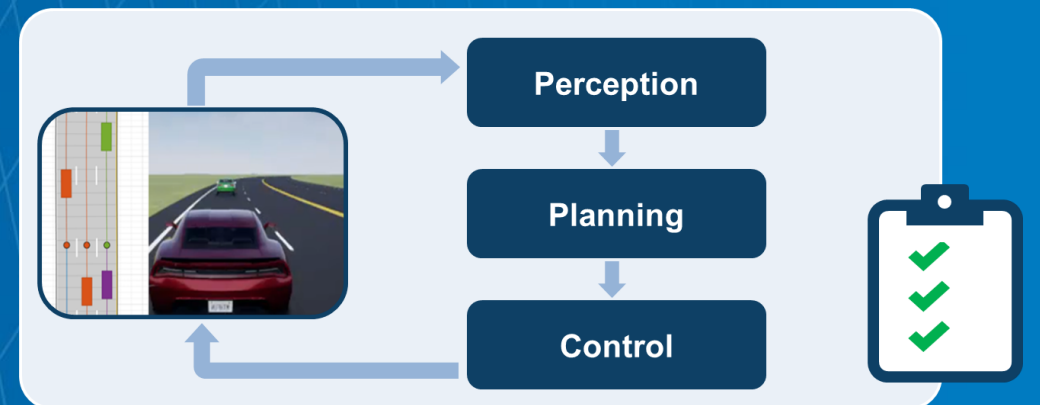


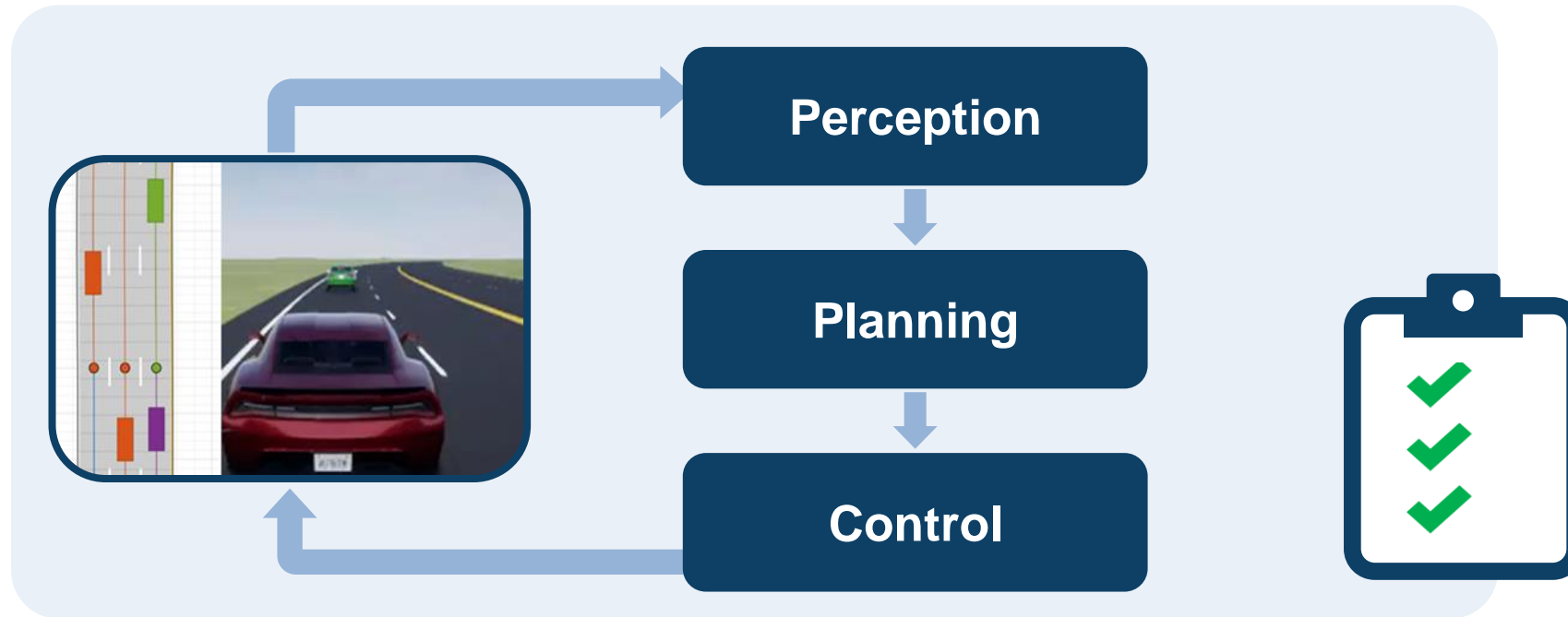
What's New in MATLAB and Simulink for ADAS and Automated Driving



Mark Corless
Automated Driving Segment Manager



Some common questions from automated driving engineers

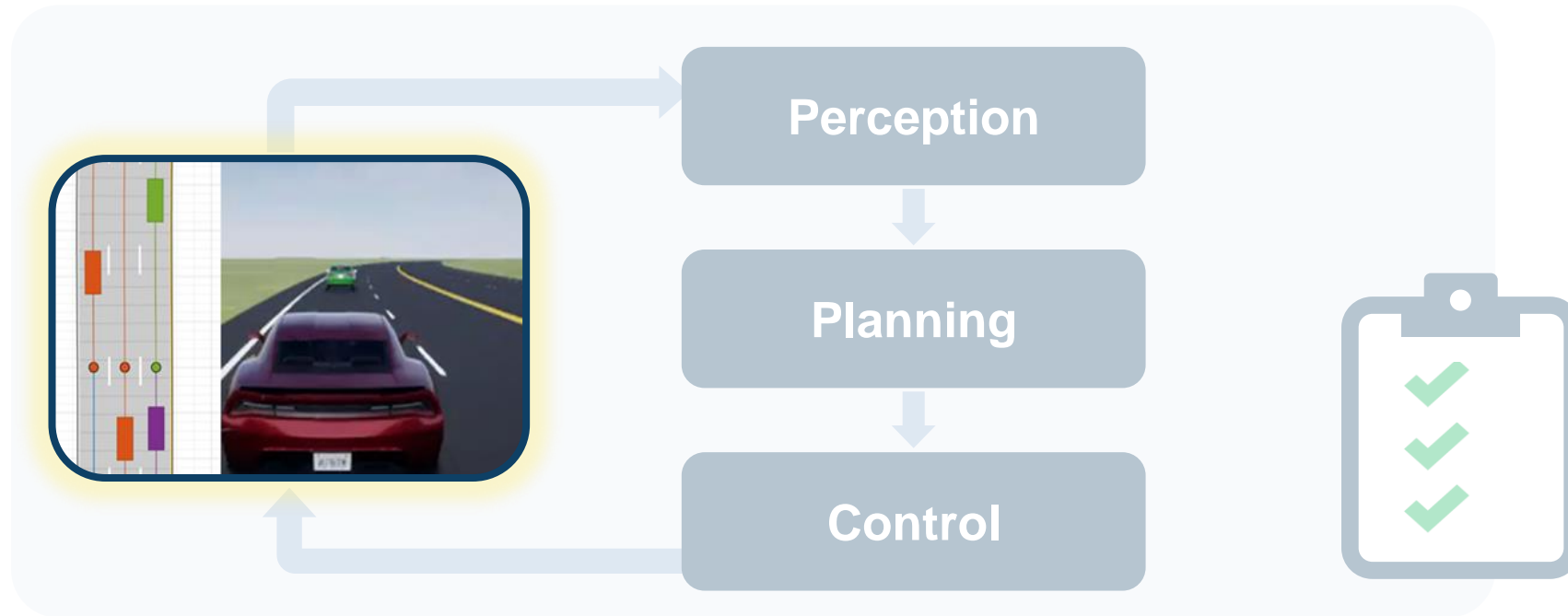


How can I
analyze & synthesize
scenarios?

How can I
design & deploy
algorithms?

How can I
integrate & test
systems?

Some common questions from automated driving engineers



How can I
analyze & synthesize
scenarios?

How can I
design & deploy
algorithms?

How can I
integrate & test
systems?

Analyze and synthesize scenarios

Real-world data workflows

Access

Visualize

Label

Enables
open loop
workflows

Synthetic scenario workflows

Create scenes

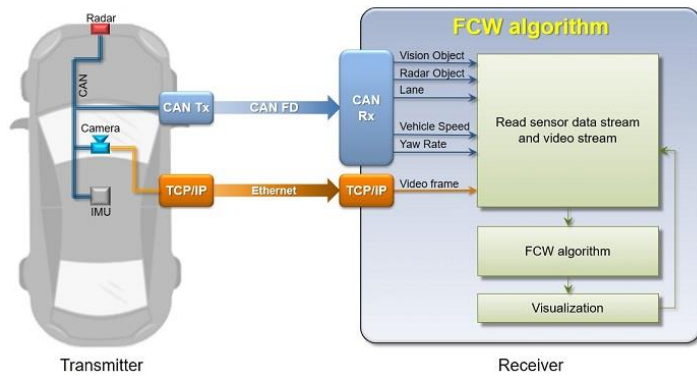
Model actors

Model sensors

Enables
open loop and
closed loop
workflows

Access recorded and live data

CAN



[Forward Collision Warning with CAN FD and TCP/IP](#)

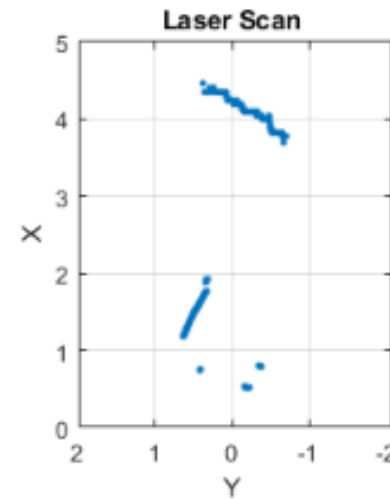
Automated Driving Toolbox™

Vehicle Network Toolbox™

Instrument Control Toolbox™

R2018a

ROS ROS 2.0



[Work with Specialized ROS Messages](#)

ROS Toolbox™

R2019b

HERE HD Live Map



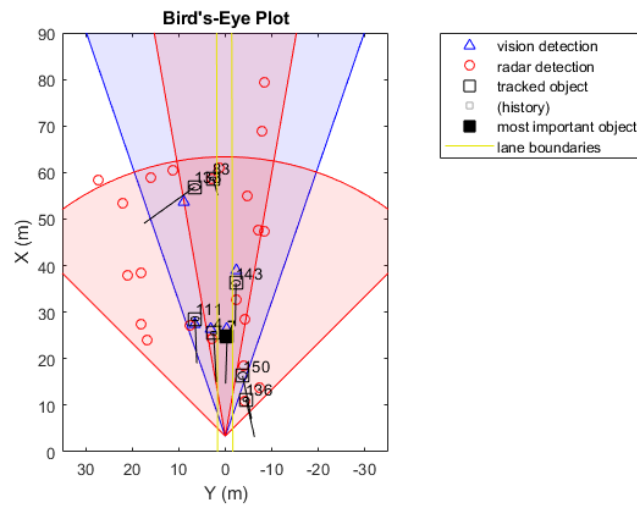
[Use HERE HD Live Map Data to Verify Lane Configurations](#)

Automated Driving Toolbox™

R2019a

Visualize vehicle data

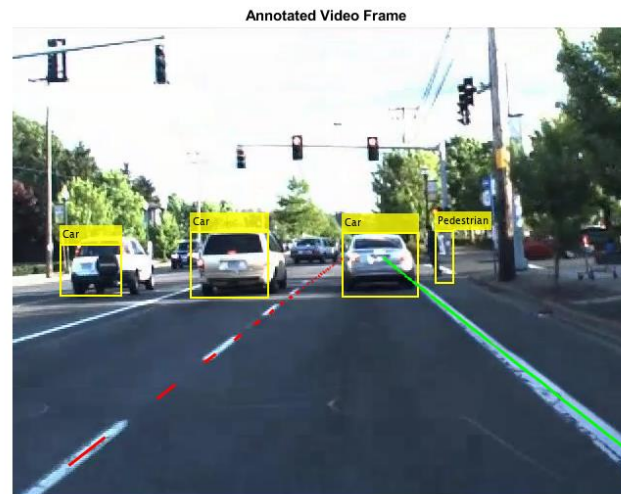
Detections



Visualize Sensor Coverage, Detections, and Tracks
Automated Driving Toolbox™

R2017a

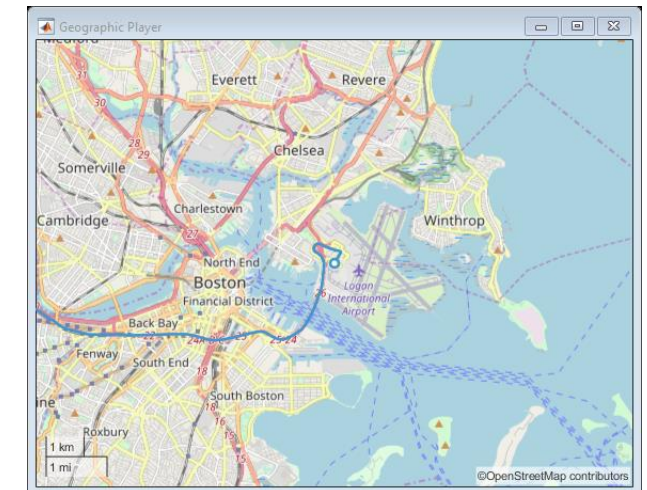
Images



Annotate Video Using Detections in Vehicle Coordinates
Automated Driving Toolbox™

R2017a

Maps



Display Data on OpenStreetMap Basemap
Automated Driving Toolbox™

R2018a

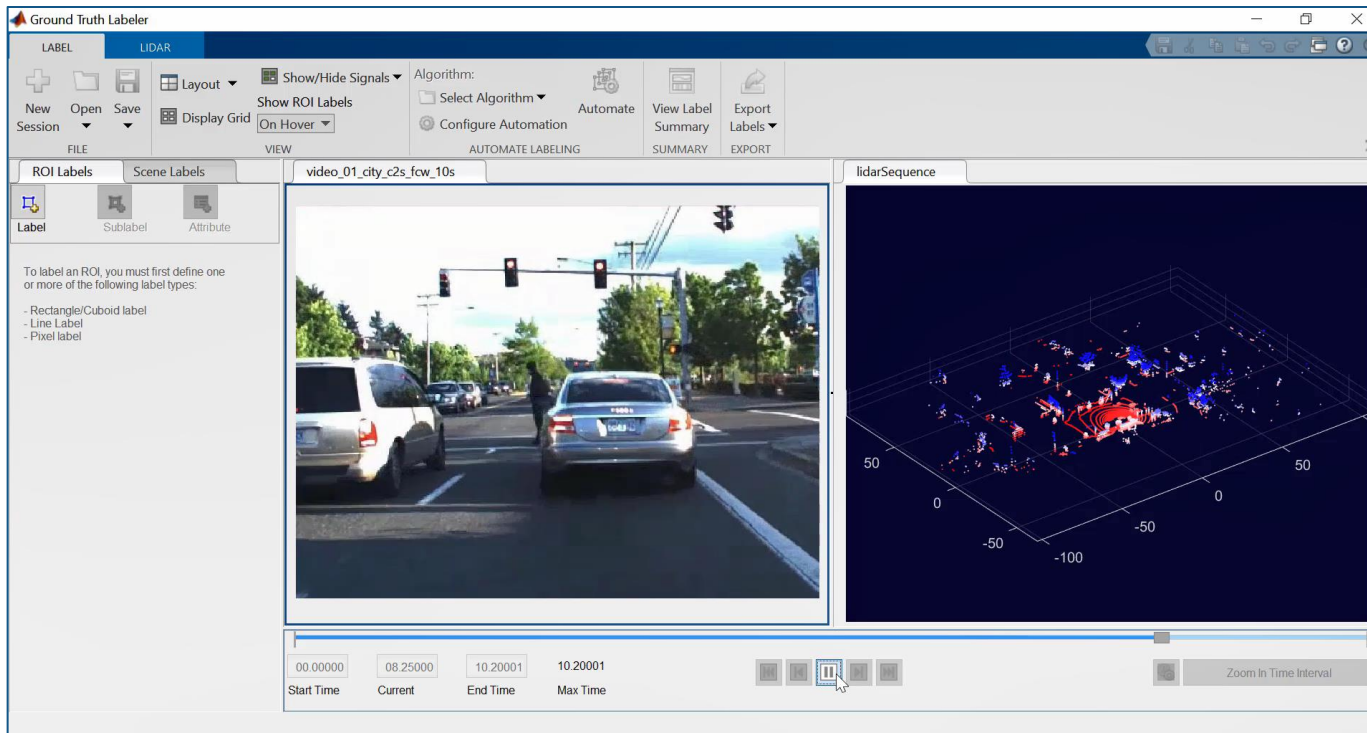
Label camera and lidar data

Visualize
multiple signals

Interactively
label

Automate
labeling

Export
labels



- Load multiple time-overlapped signals representing the same scene
- Synchronously explore data

[Get Started with the Ground Truth Labeler](#)

Automated Driving Toolbox™

Updated **R2020a**

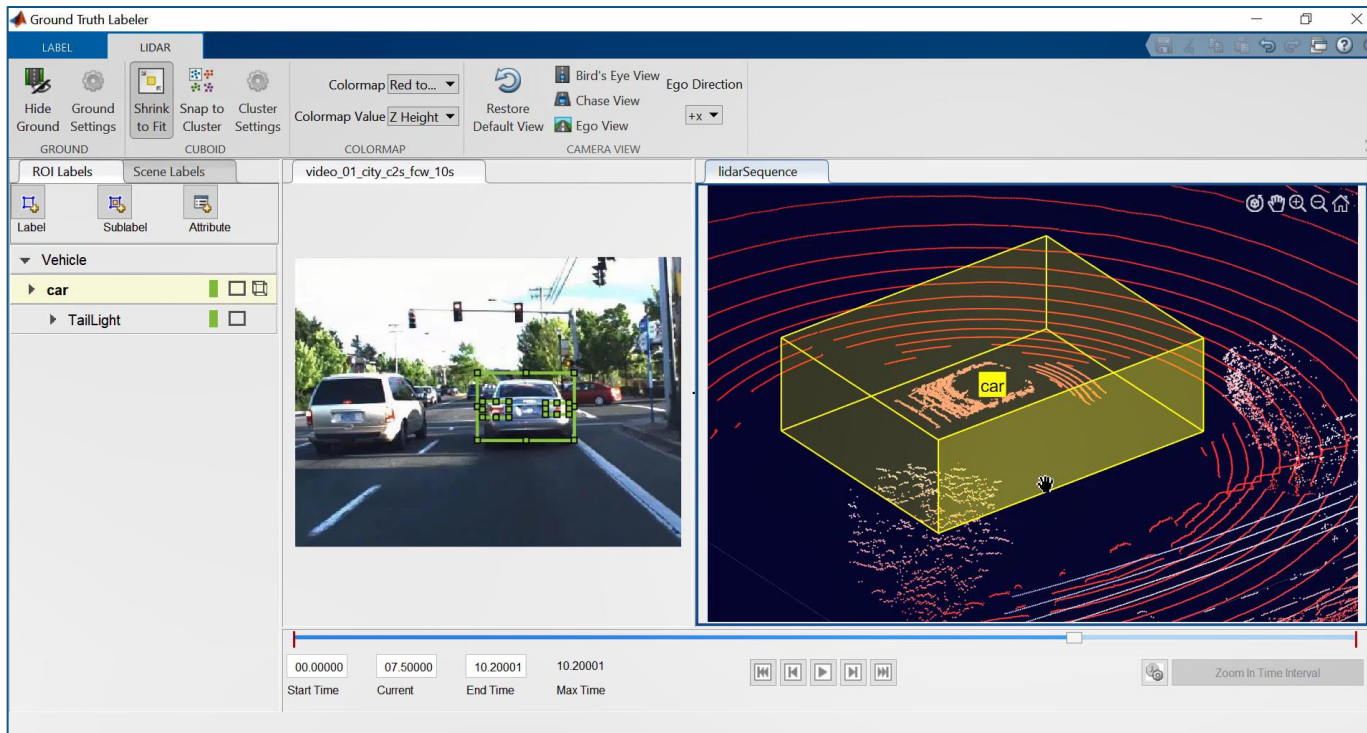
Label camera and lidar data

Visualize
multiple signals

Interactively
label

Automate
labeling

Export
labels



- Interactively label sensor data
 - Rectangular region of interest (ROI)
 - Polyline ROI
 - Pixel ROI (semantic segmentation)
 - Cuboid (lidar)
 - Scenes

[Get Started with the Ground Truth Labeler](#)

Automated Driving Toolbox™

Updated **R2020a**

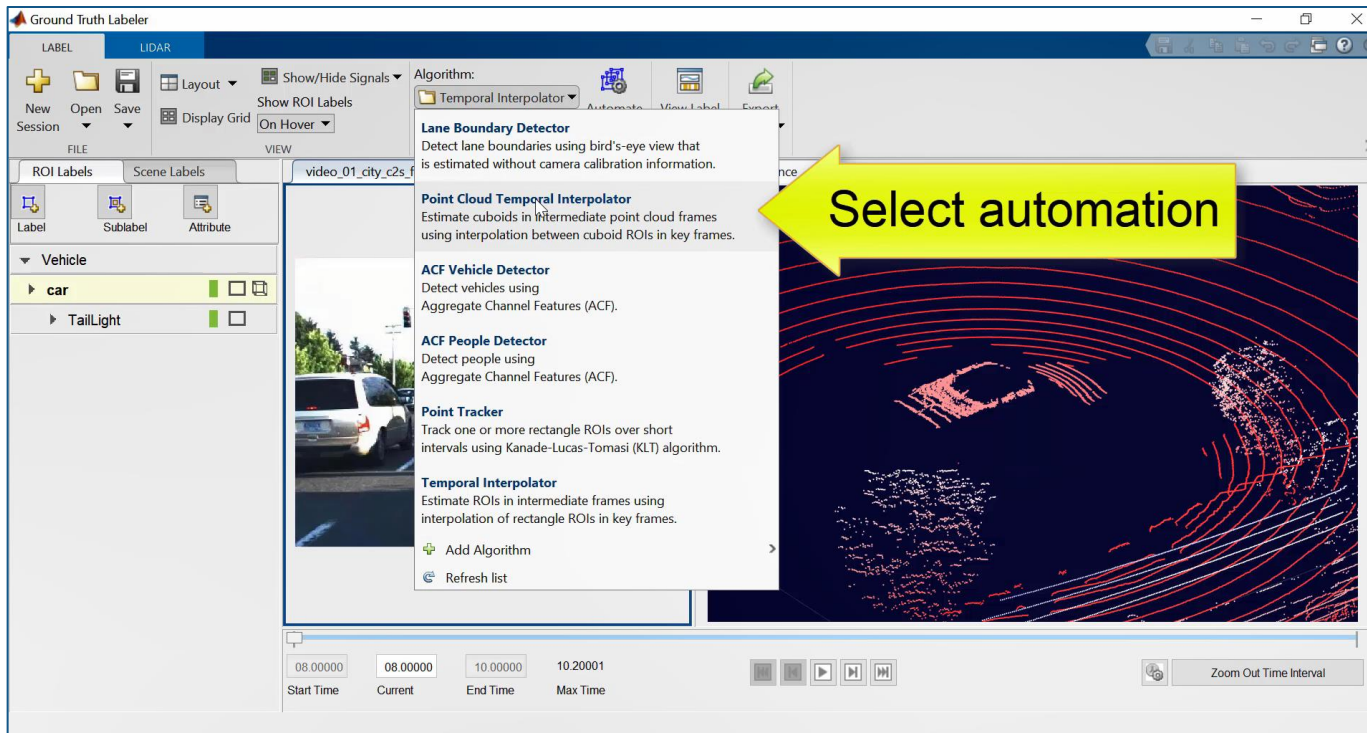
Label camera and lidar data

Visualize
multiple signals

Interactively
label

Automate
labeling

Export
labels



- Get started with built-in detection and tracking algorithms
- Extend workflow by registering custom automation algorithms

[Get Started with the Ground Truth Labeler](#)

Automated Driving Toolbox™

Updated **R2020a**

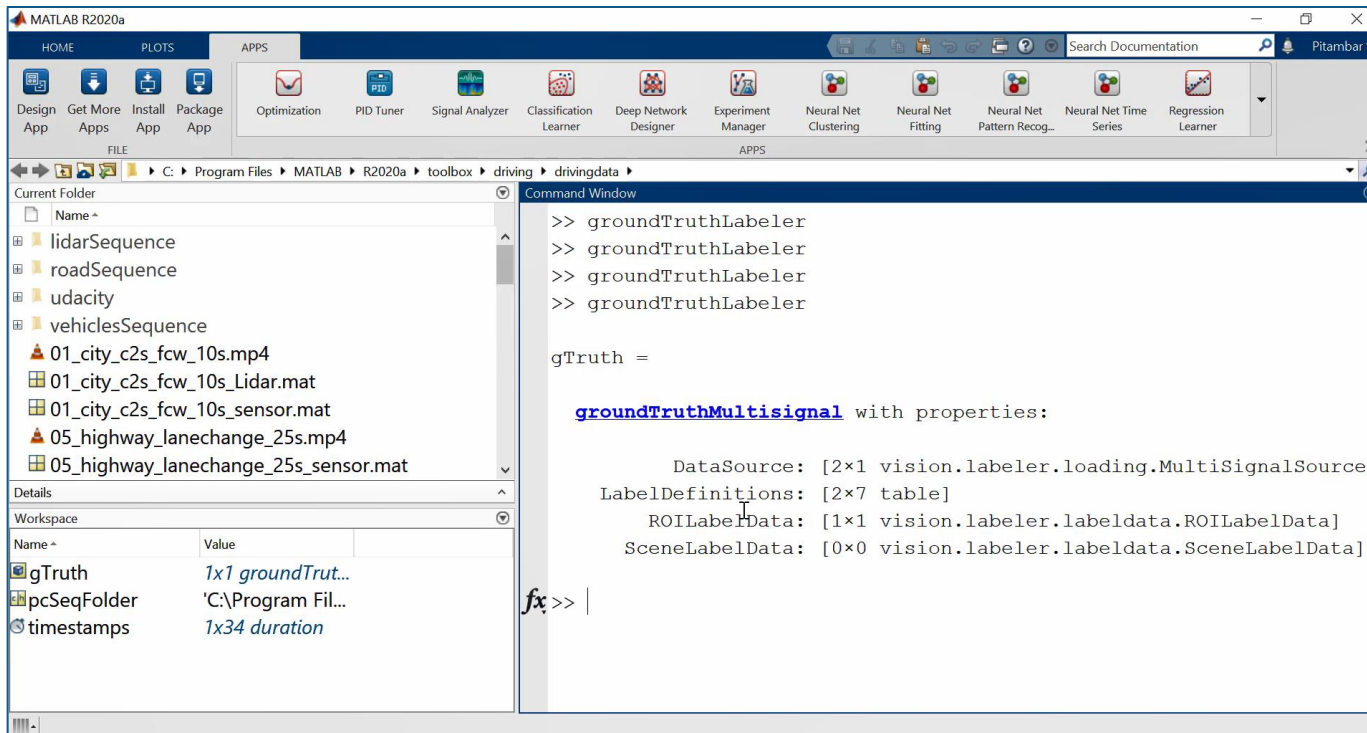
Label camera and lidar data

Visualize
multiple signals

Interactively
label

Automate
labeling

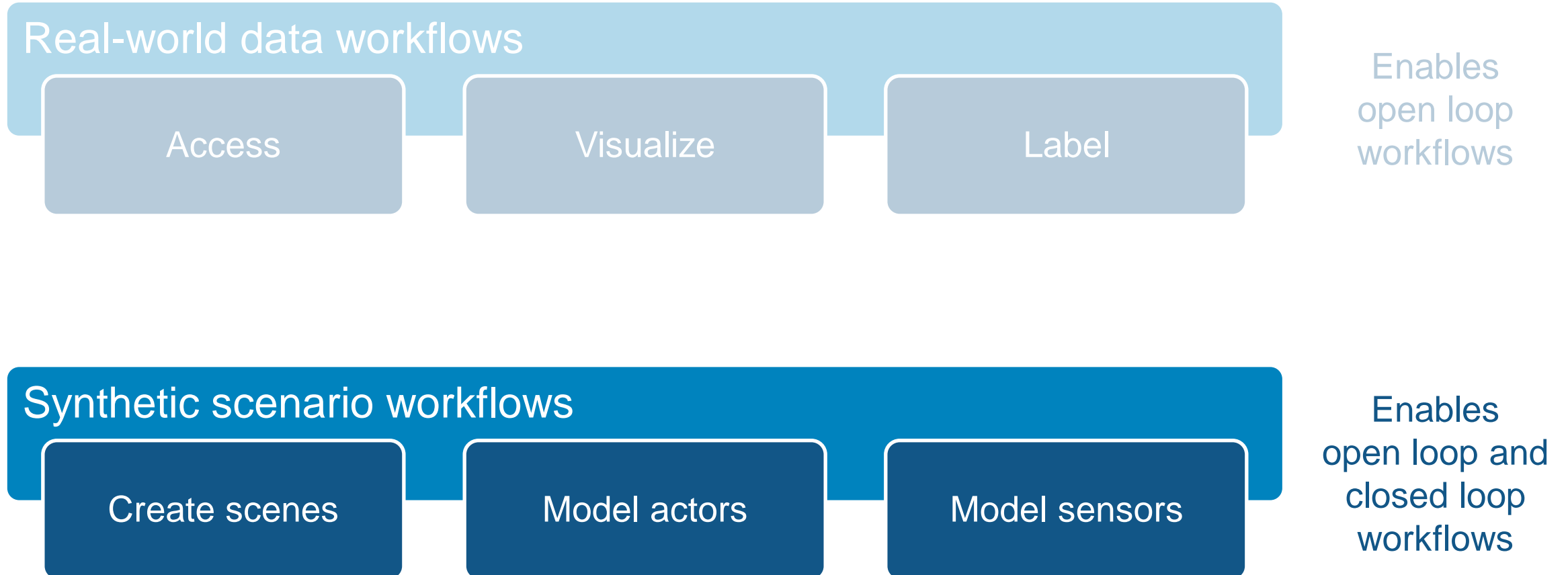
Export
labels



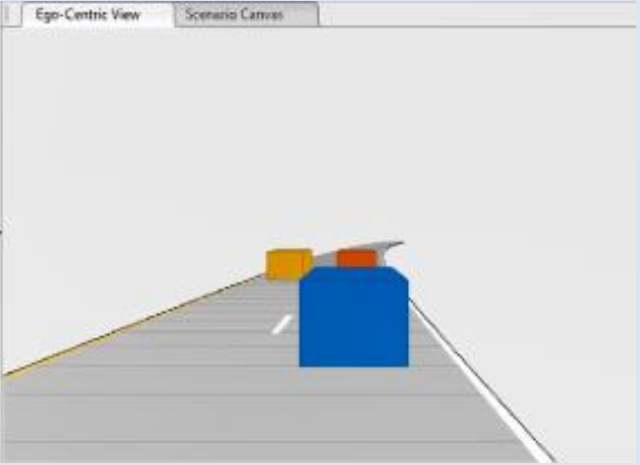
- Export to workspace or file
- Enables workflows to customize format of labels for integration with other tools

[Get Started with the Ground Truth Labeler](#)
Automated Driving Toolbox™
 Updated **R2020a**

Analyze and synthesize scenarios

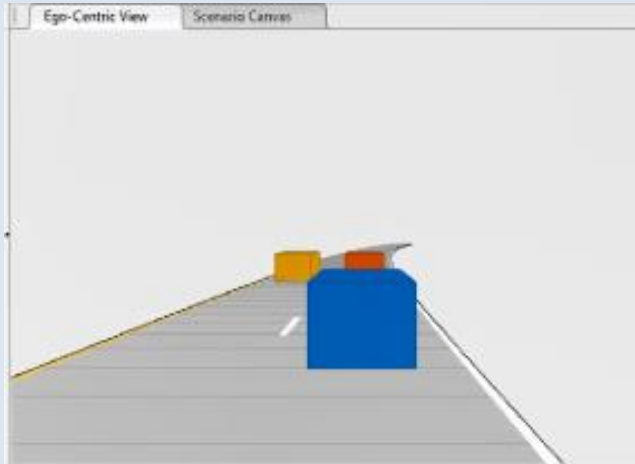


Synthesize scenarios to test algorithms and systems

Scenes	Cuboid  A screenshot of a simulation window titled "Ego-Centric View" and "Scenario Canvas". The view shows a blue vehicle (the ego) on a road, with a yellow cube and a red cube positioned ahead of it. The road is flanked by grey walls.
Testing	Controls, sensor fusion, planning
Sensing	Probabilistic vision (detection list) Probabilistic lane (detection list) Probabilistic radar (detection list) Lidar (point cloud)

Synthesize scenarios to test algorithms and systems

Scenes	Cuboid	Unreal Engine
Testing	Controls, sensor fusion, planning	Controls, sensor fusion, planning, perception
Sensing	Probabilistic vision (detection list) Probabilistic lane (detection list) Probabilistic radar (detection list) Lidar (point cloud)	Monocular camera (image, labels, depth) Fisheye camera (image) Probabilistic radar (detection list) Lidar (point cloud)



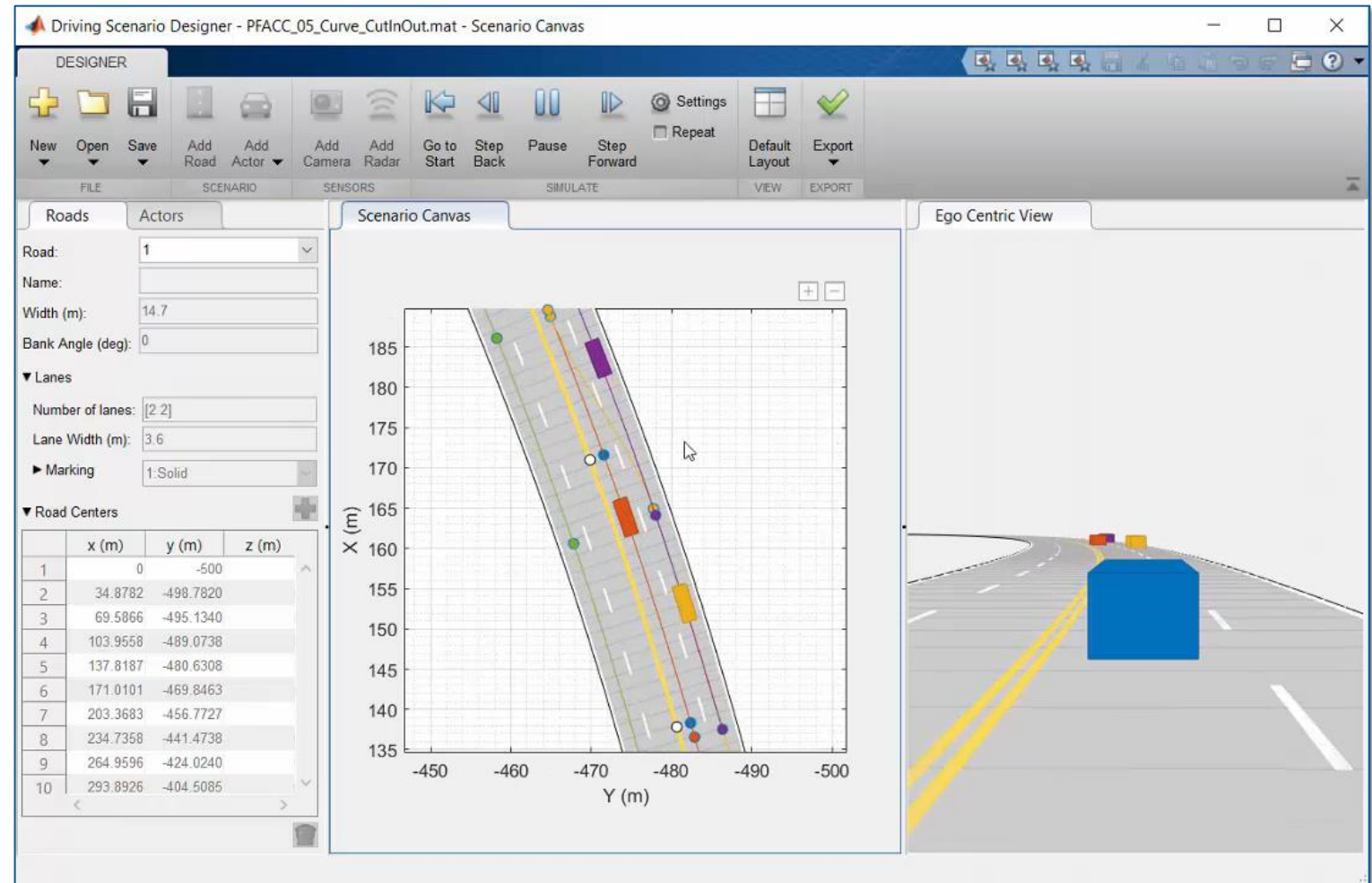
Graphically author scenarios with Driving Scenario Designer

- Design scenes
 - Roads, Lane markings
 - Pre-built scenes (Euro NCAP)
- Import roads
 - OpenDRIVE, HERE HD Live Map
- Add actors
 - Size, Radar cross-section (RCS)
 - Trajectories
- Export scenarios
 - MATLAB code, Simulink model

[Driving Scenario Designer](#)

Automated Driving Toolbox™

Updated **R2020a**



Synthesize driving scenarios from recorded data



Simulate synthesized scenario

Summary
This example shows how to automatically generate a virtual driving scenario from vehicle data recorded using the GPS and lidar sensors.

Helper Functions

helperGetEgoData
This function reads the ego vehicle data from a text file and converts into a structure.

```

function [egoData] = helperGetEgoData(egoFile)
%Read the ego vehicle data from text file
fileID = fopen(egoFile);
content = textscan(fileID, '%f %f %f');
fields = {'lat', 'lon', 'Time'};
egoData = cell2struct(content, fields, 2);
fclose(fileID);
end
  
```

helperGetNonEgoData
This function reads the processed lidar data from a text file and converts into a structure. The processed lidar data contains information about the

- Import roads from OpenDRIVE
- Create ego trajectory from GPS
- Create target trajectories object lists

[Scenario Generation from Recorded Vehicle Data](#)

Automated Driving Toolbox™

R2019a

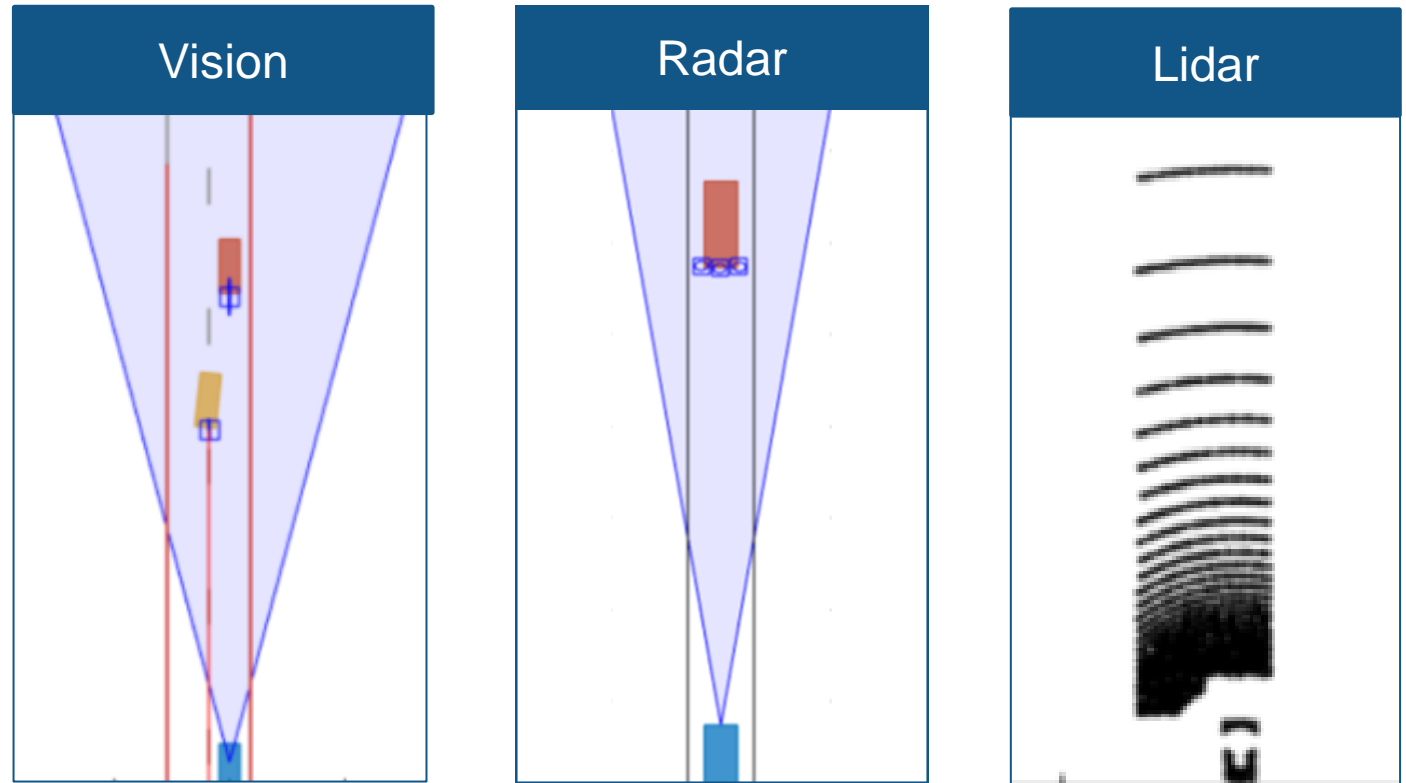
Model sensors in cuboid driving scenarios

- Vision object detections
- Vision lane detections
- Radar detections
- Lidar point cloud

[Cuboid Driving Scenario Simulation](#)

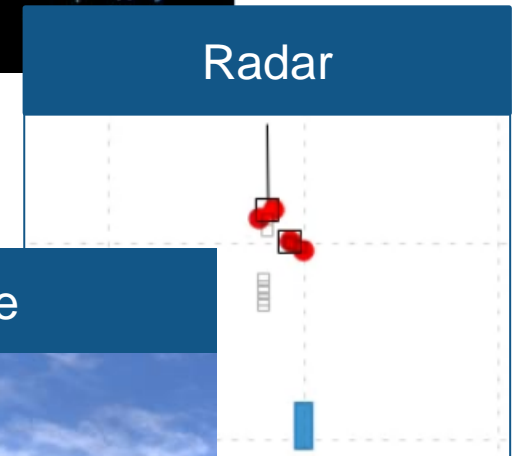
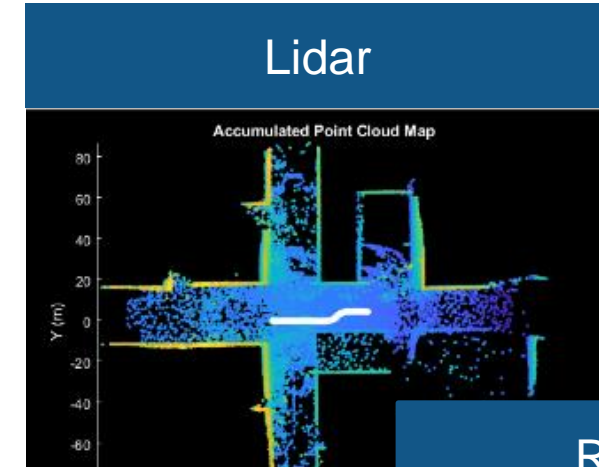
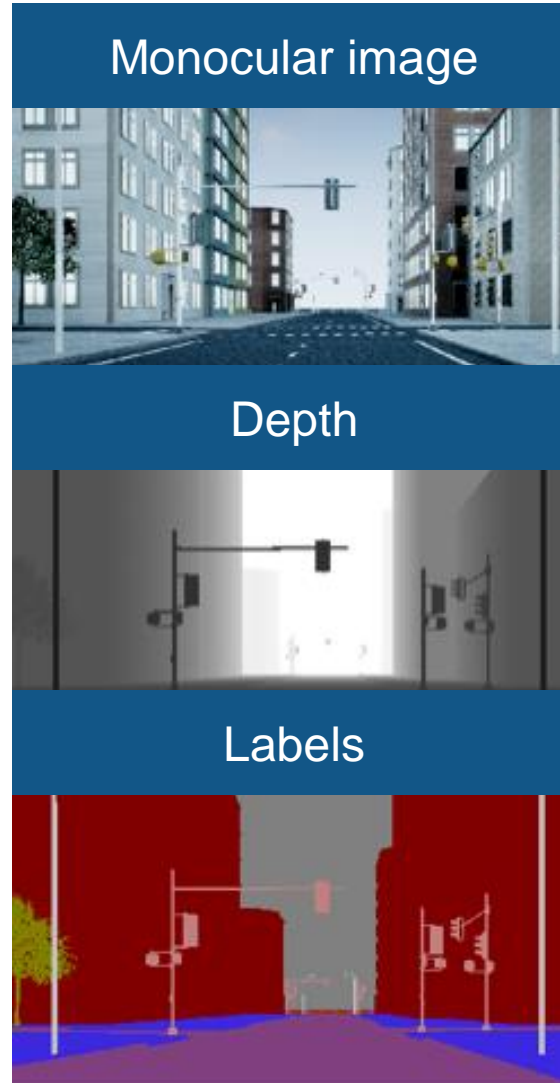
Automated Driving Toolbox™

Updated **R2020a**



Model sensors in Unreal Engine driving scenarios

- Monocular camera
 - Image
 - Depth
 - Labels
- Fisheye camera image
- Lidar point cloud
- Radar detections

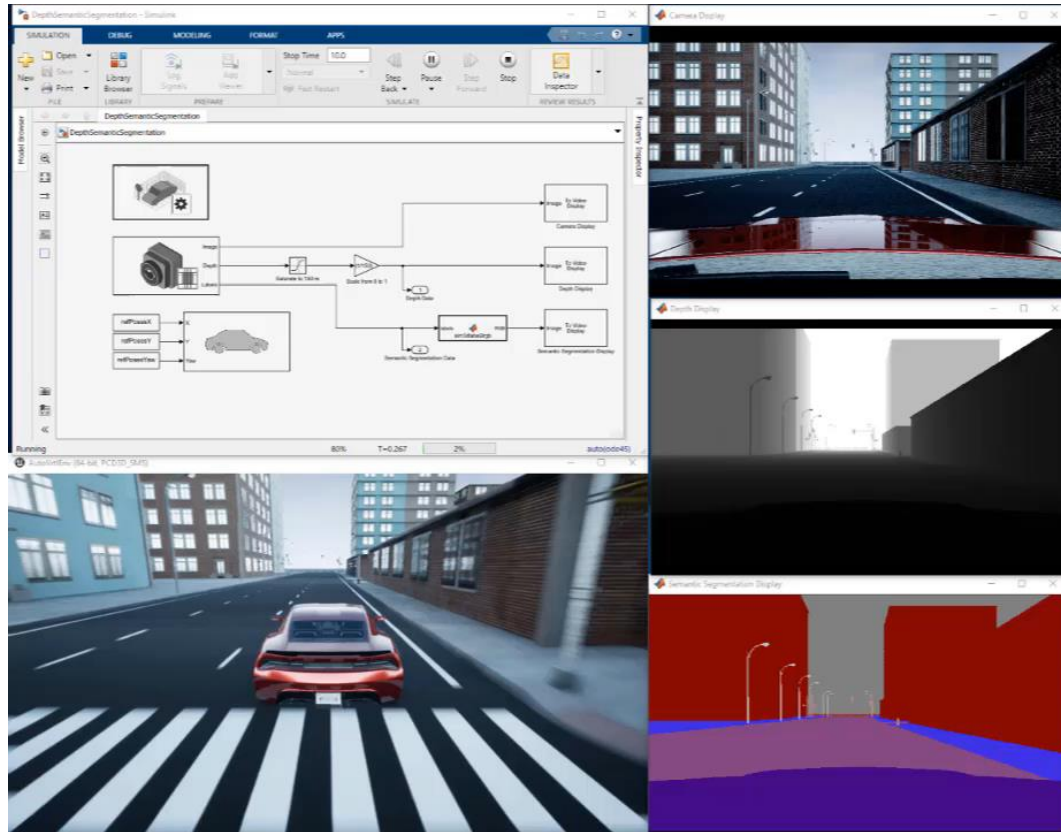


[3D Simulation for Automated Driving](#)

Automated Driving Toolbox™

Updated **R2020a**

Model monocular camera sensor in Unreal Engine driving scenario



[Visualize Depth and Semantic Segmentation Data in 3D Environment](#)

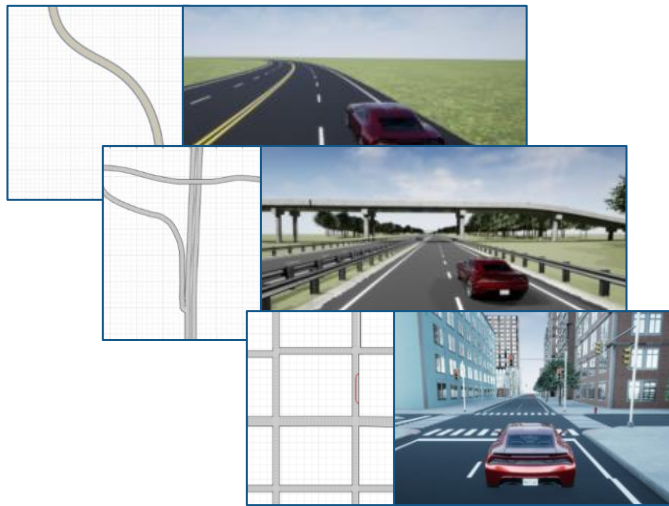
[Environment](#)

Automated Driving Toolbox™

R2019b

Design with cuboid and Unreal Engine driving scenarios

Scenes

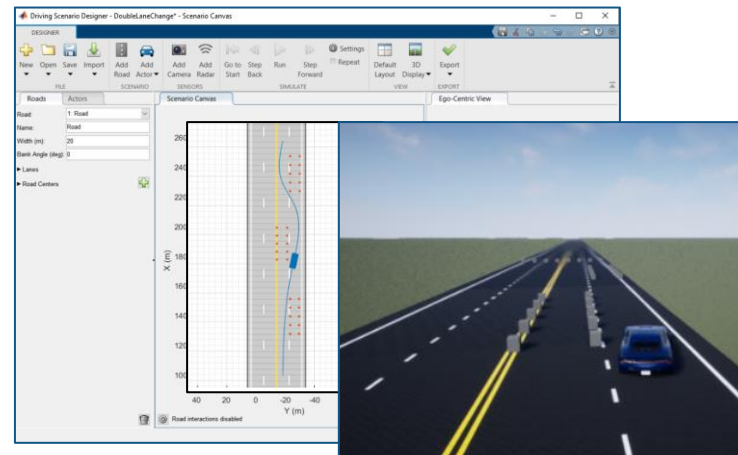


[Cuboid Versions of 3D Simulation Scenes in Driving Scenario Designer](#)

Automated Driving Toolbox™

R2020a

Trajectories

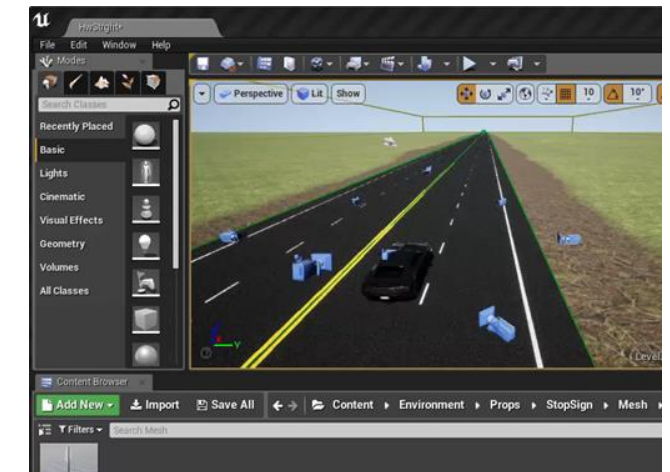


[Specify Vehicle Trajectories for 3D Simulation](#)

Automated Driving Toolbox™

R2020a

Customize scenes

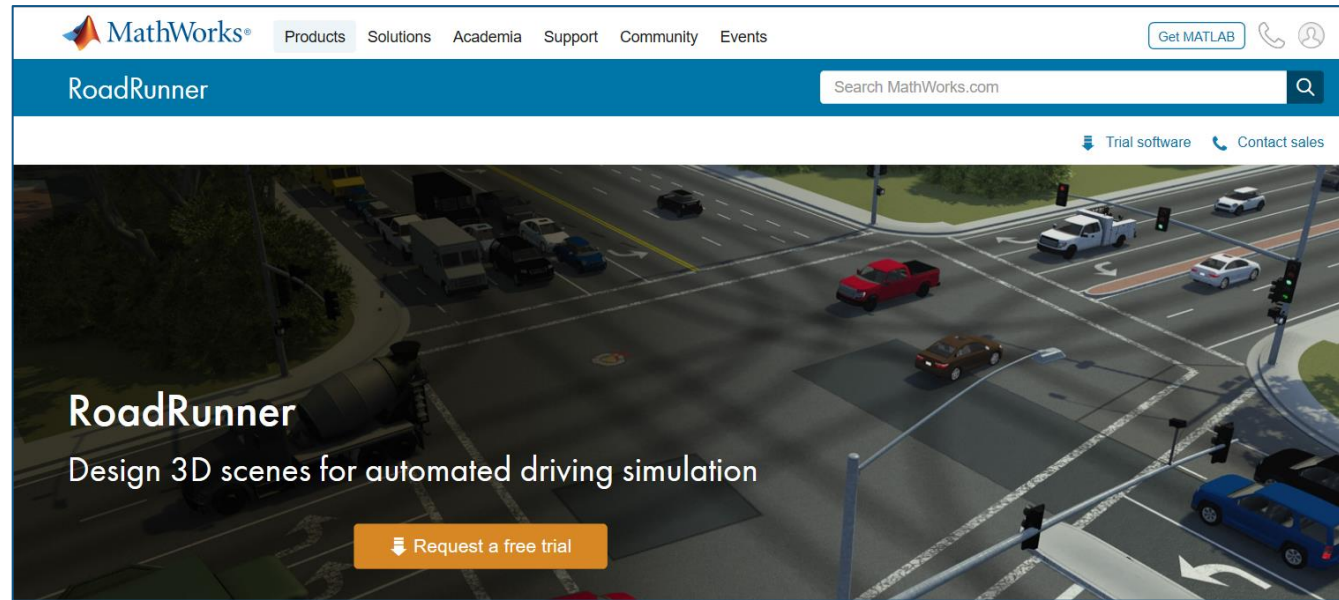


[Customize 3D Scenes for Automated Driving](#)

Automated Driving Toolbox™

R2020a

Design 3D scenes for automated driving simulation



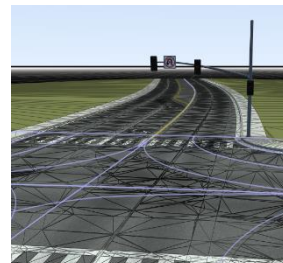
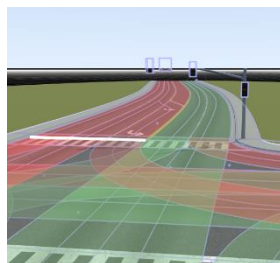
R2020a

Update 1

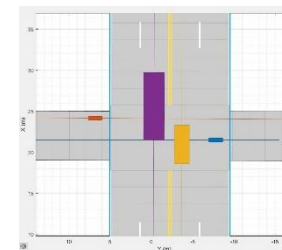
New base product

Does not require MATLAB

External Simulators

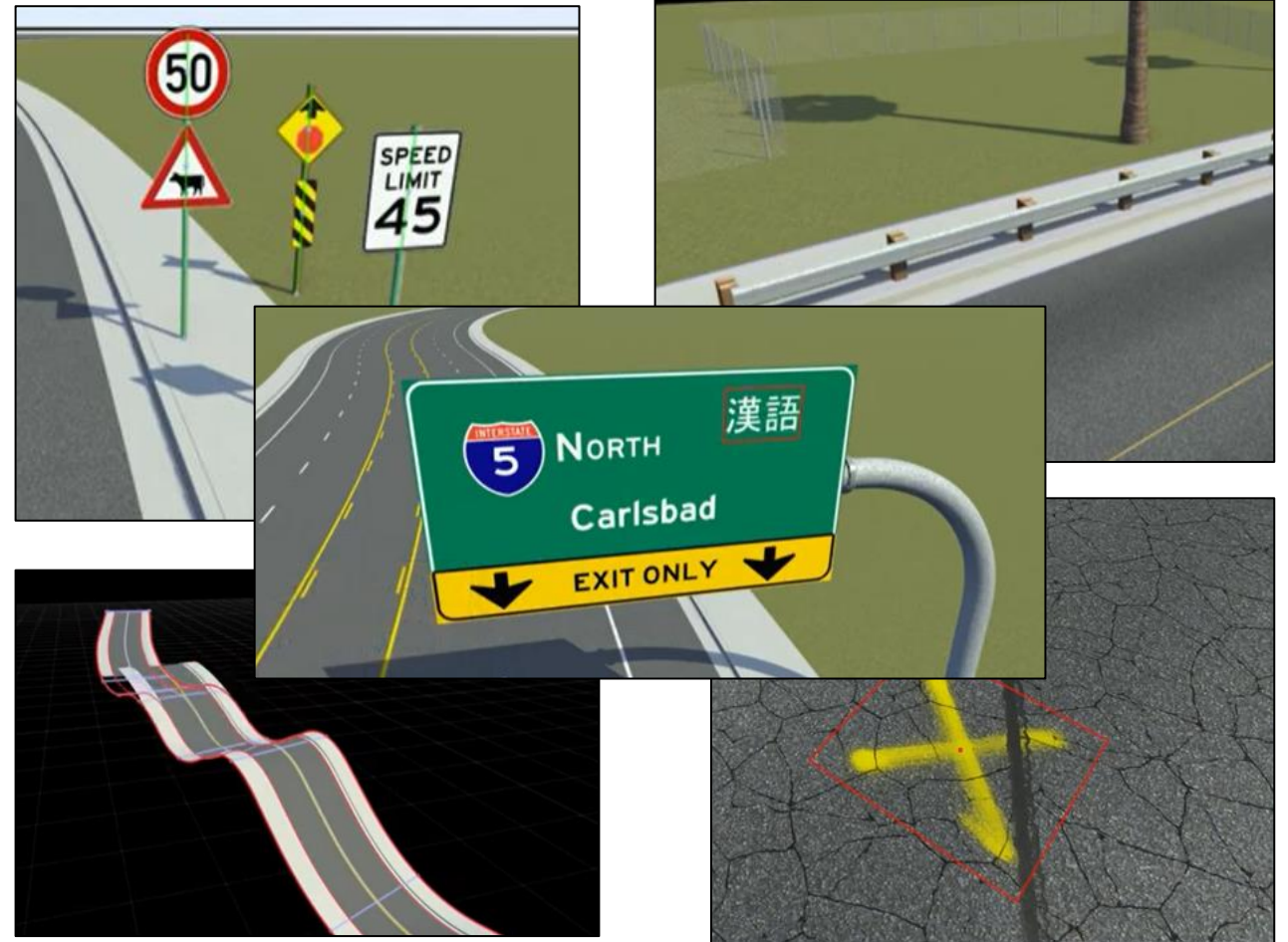


MATLAB & Simulink



Design scenes with road, marking, and prop assets

- Roads and markings
- Traffic signals
- Guard rails
- Trees
- Signs
- Elevation data



[Assets](#)

RoadRunner™

R2020a

Update 1

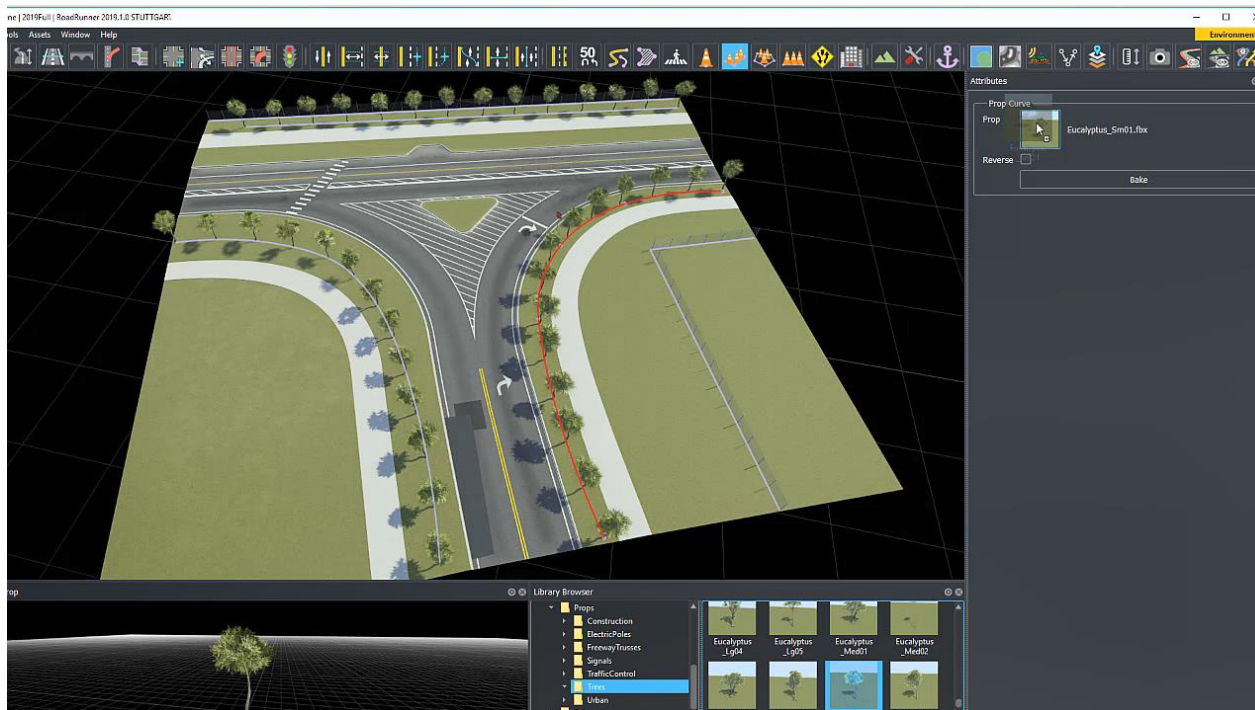
Design scenes and export to driving simulator

Design
scenes

Export
meshes

Import to
simulator

Simulate



- Edit roads
- Edit road materials
- Add road markings

[Exporting to CARLA](#)

RoadRunner™

R2020a

Update 1

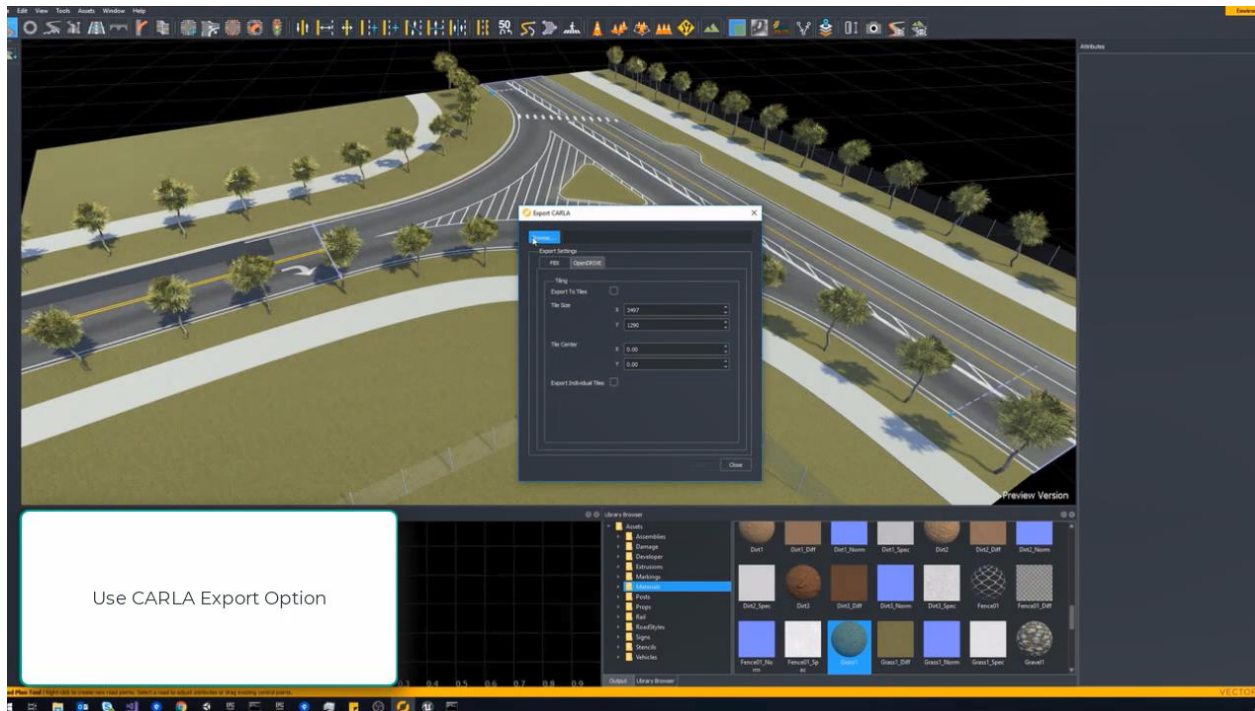
Design scenes and export to driving simulator

Design
scenes

Export
meshes

Import to
simulator

Simulate



- Install plugin
- Export from RoadRunner
- Import into CARLA/Unreal

[Exporting to CARLA](#)

RoadRunner™

R2020a

Update 1

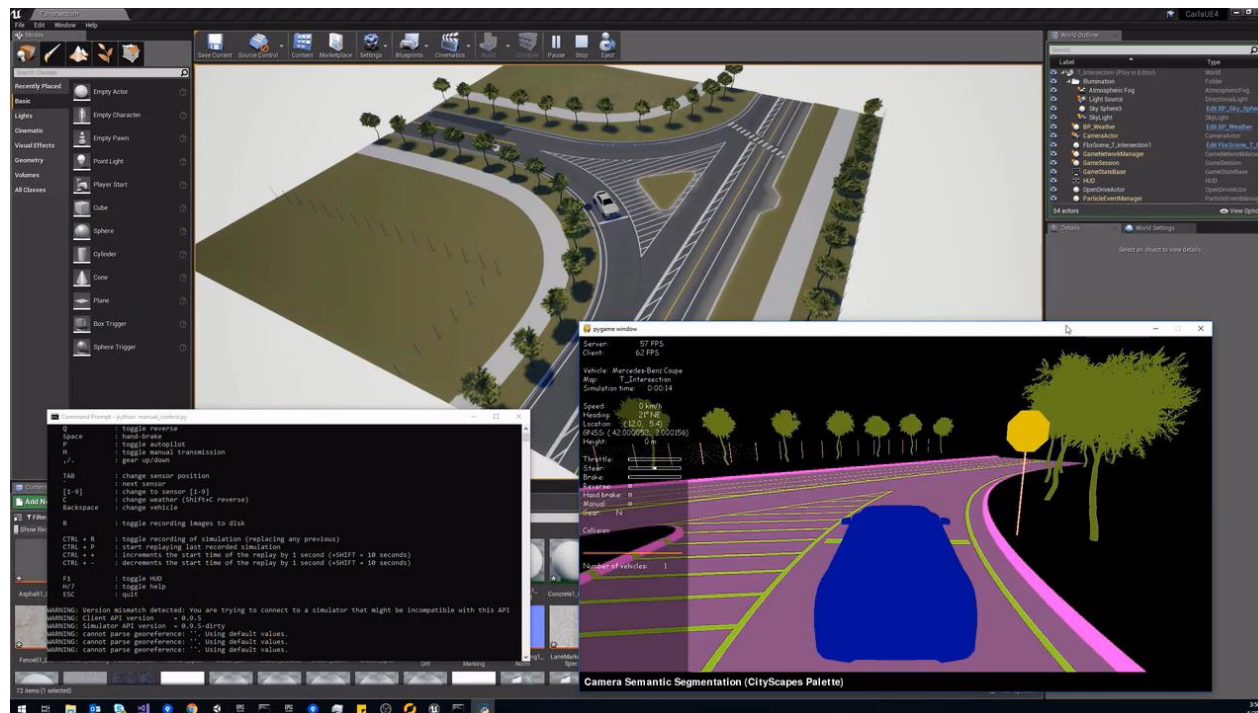
Design scenes and export to driving simulator

Design scenes

Export meshes

Import to simulator

Simulate



- Move vehicle in automated driving simulation
- Visualize pixels IDs for semantic segmentation

[Exporting to CARLA](#)

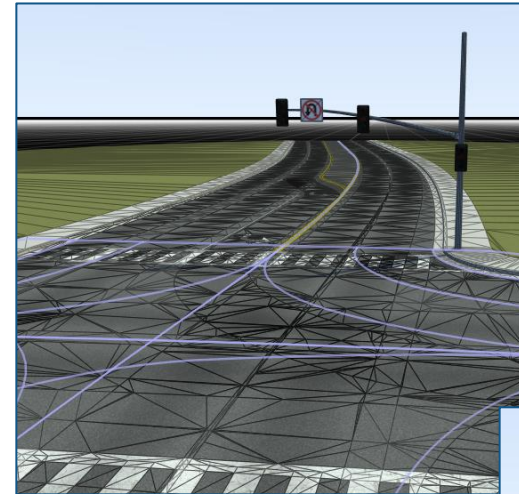
RoadRunner™

R2020a

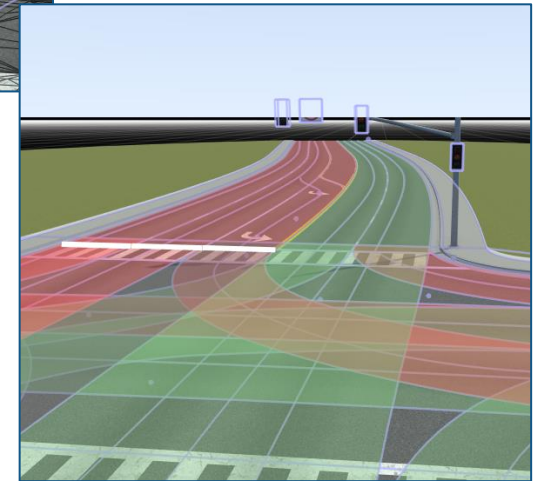
Update 1

Export scenes to file formats and driving simulators

- Export to common file formats for use in third-party applications
 - Filmbox (.fbx), OpenDRIVE (.xodr)
 - Unreal Engine[®], CARLA
 - Unity[®], LGSVL, GeoJSON
 - VIRES Virtual Test Drive, Metamoto
 - IPG Carmaker, Cognata, Baidu Apollo
 - Tesis Dynaware, TaSS PreScan
 - Universal Scene Description (USD)



FBX
(meshes)



OpenDRIVE
(semantics)

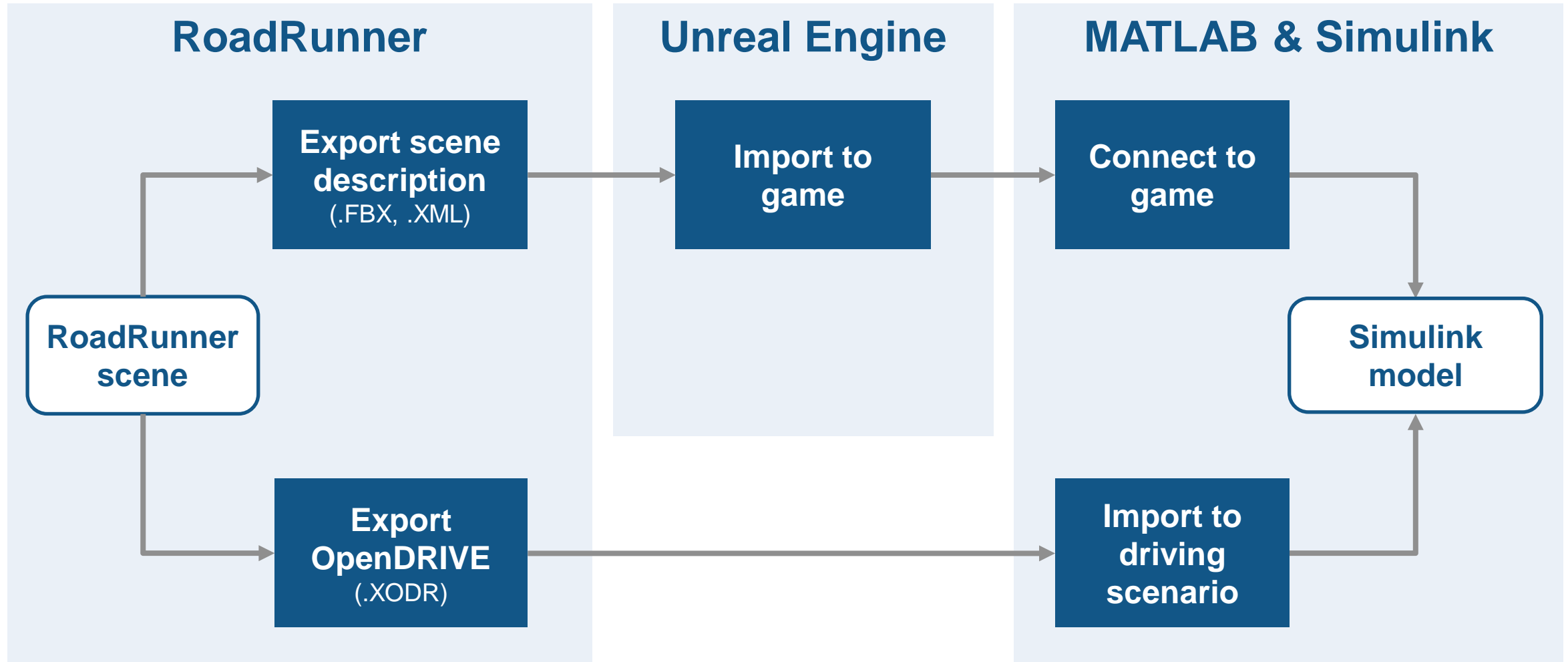
[Exporting](#)

RoadRunner™

R2020a

Update 1

Integrate RoadRunner with MATLAB and Simulink workflows



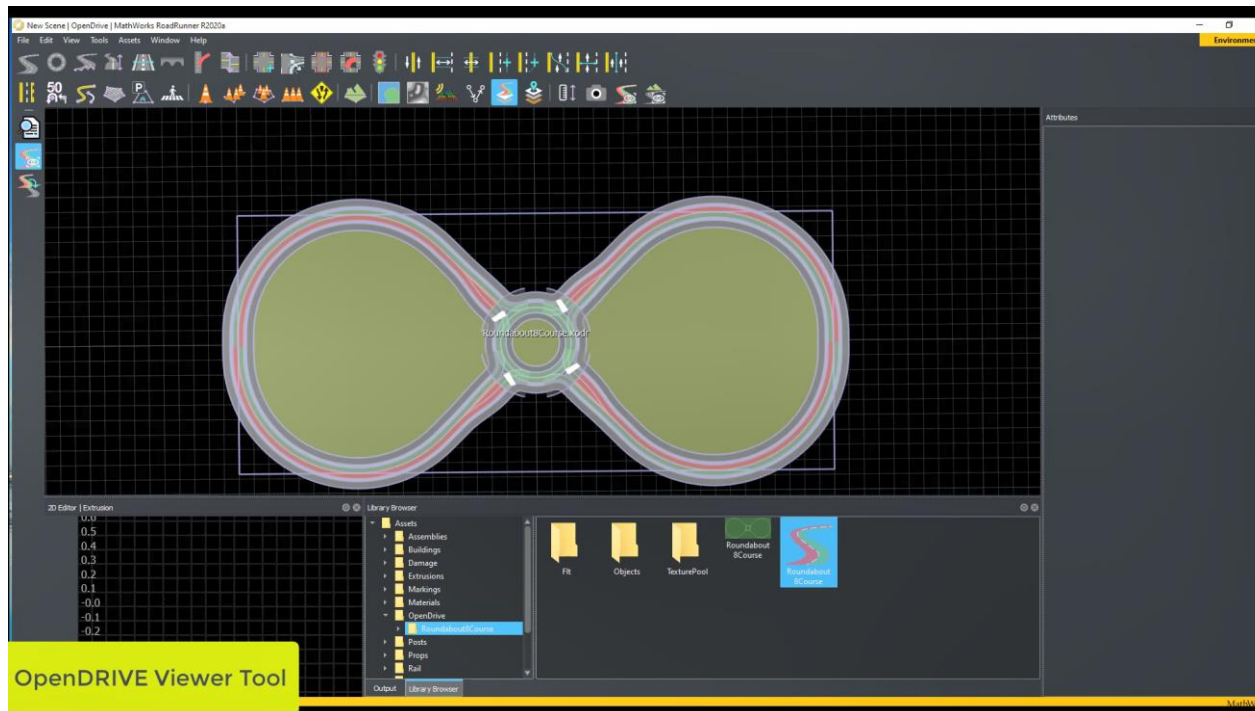
Import, visualize, and edit OpenDRIVE files

Import
OpenDRIVE

Visualize

Edit

Export



- Validate OpenDRIVE file
- Import and visualize
- Edit roads and scene
- Export to common driving simulator formats (including OpenDRIVE)

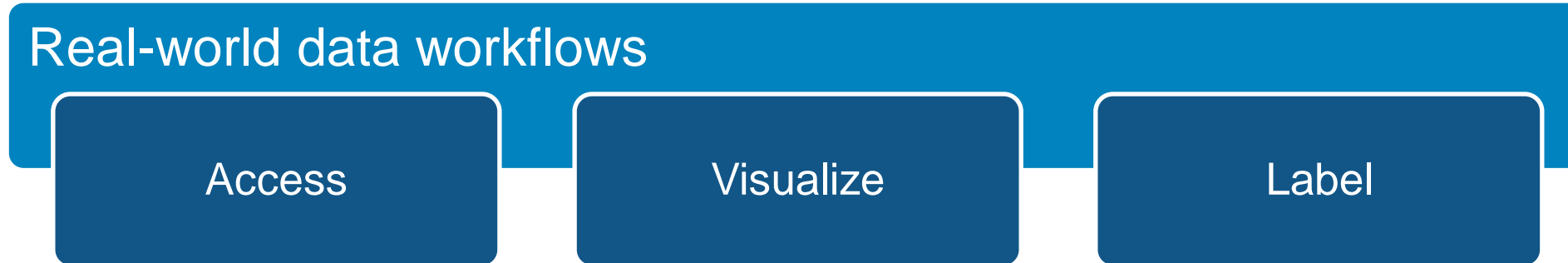
[Importing OpenDRIVE Files](#)

RoadRunner™

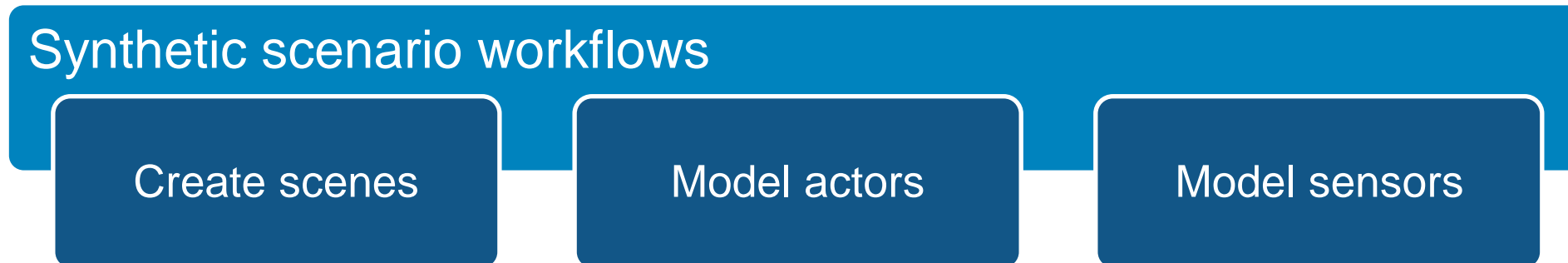
R2020a

Update 1

Analyze and synthesize scenarios

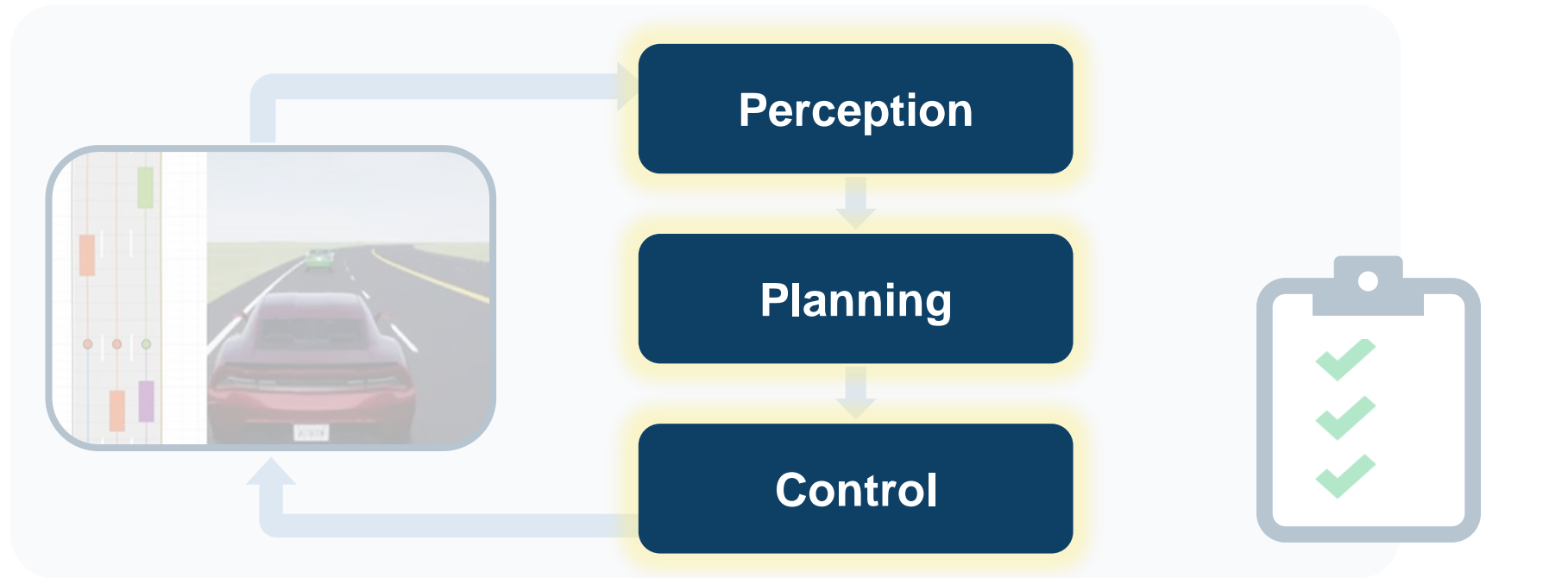


Enables open loop workflows



Enables open loop and closed loop workflows

Some common questions from automated driving engineers



How can I
analyze & synthesize
 scenarios?

How can I
design & deploy
 algorithms?

How can I
integrate & test
 systems?

Design and deploy algorithms

Planning & control workflows

Motion
planning

Decision
logic

Longitudinal
controls

Lateral
controls

Perception workflows

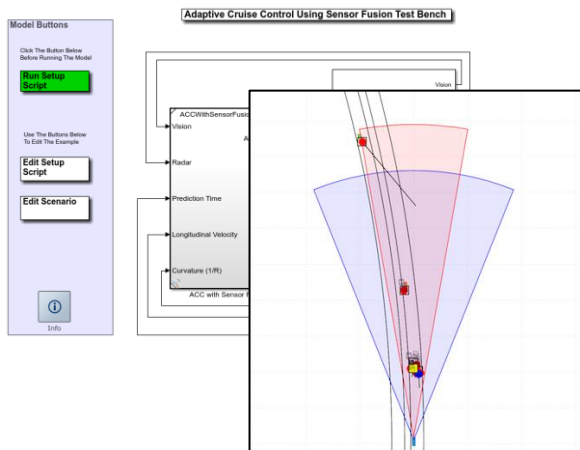
Detection

Tracking &
sensor fusion

Localization

Design controls and decision logic for ADAS

Adaptive Cruise Control (longitudinal control)

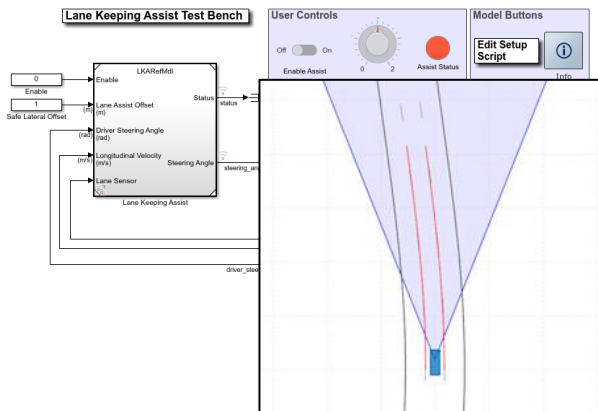


Adaptive Cruise Control with Sensor Fusion

*Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder®*

R2017b

Lane Keep Assist (Lateral control)

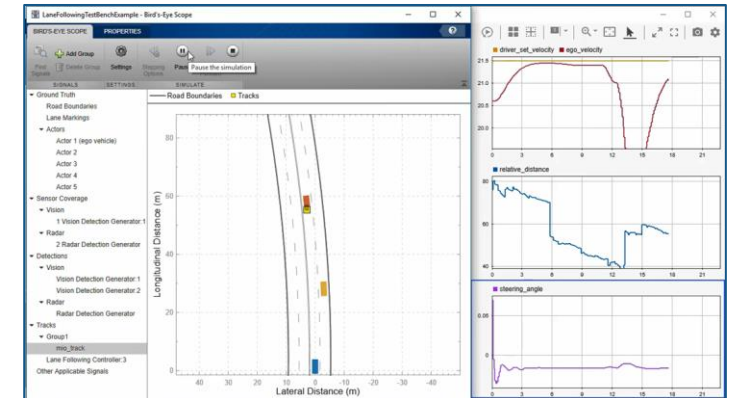


Lane Keeping Assist with Lane Detection

*Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder®*

R2018a

Lane Following (longitudinal + lateral control)

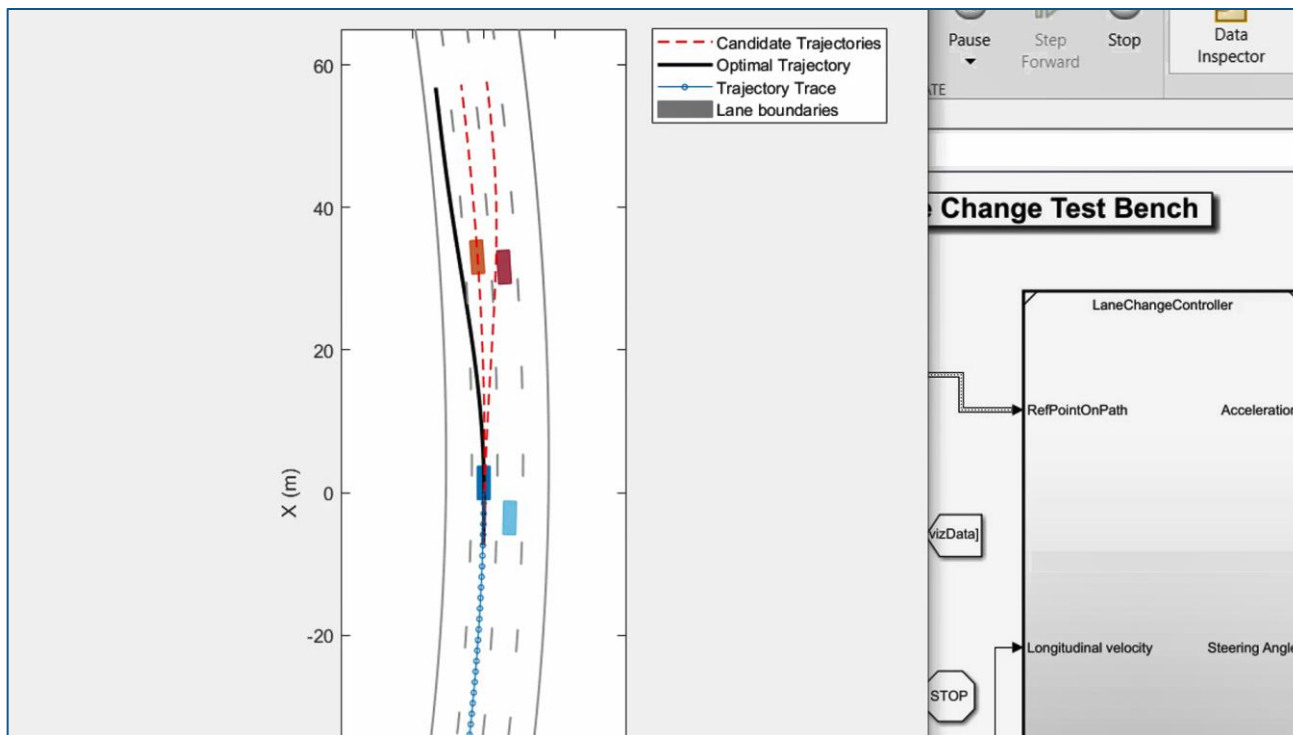


Lane Following Control with Sensor Fusion

*Model Predictive Control Toolbox™
Automated Driving Toolbox™
Embedded Coder®*

R2018b

Design planning and controls for highway lane change



- Plot candidate trajectories
- Plot selected optimal trajectory
- Plot trajectory history

[Lane Change for Highway Driving](#)

Navigation Toolbox™

Model Predictive Control Toolbox™

Automated Driving Toolbox™

Updated **R2020a**

Design planning and controls for automated parking

Design
planner & controls

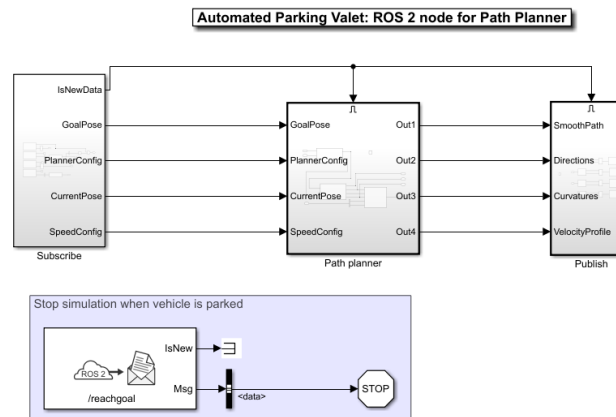


[Automated Parking Valet with Simulink](#)

Automated Driving Toolbox™

R2018a

Deploy to
ROS 2 node



[Automated Parking Valet with ROS 2 in Simulink](#)

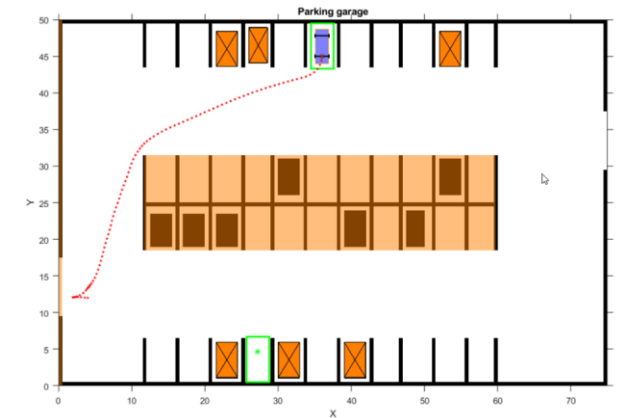
Automated Driving Toolbox™

ROS Toolbox™

Embedded Coder®

R2019b

Planner & Controller =
Nonlinear MPC



[Parking Valet using Nonlinear Model Predictive Control](#)

Automated Driving Toolbox™

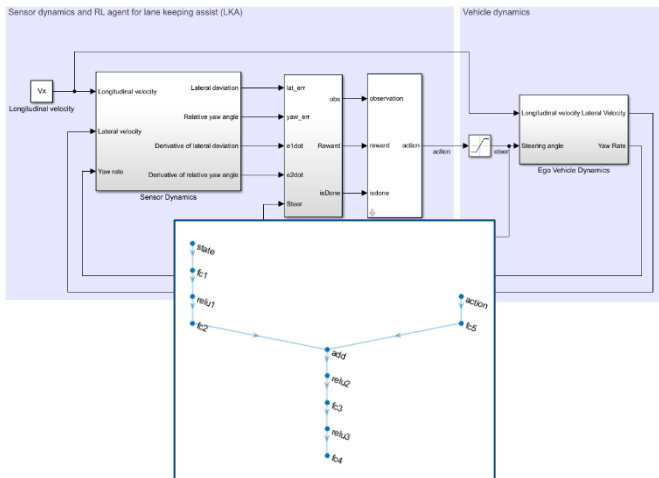
Model Predictive Control Toolbox™

Navigation Toolbox™

R2020a

Design controls with reinforcement learning

Train new network

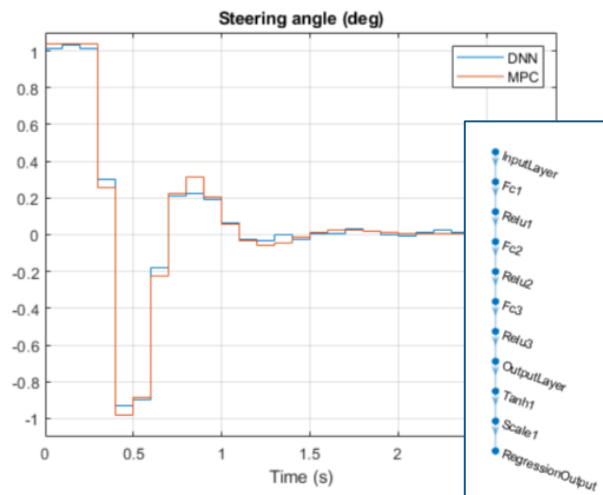


Train DQN Agent for Lane Keeping Assist

Reinforcement Learning Toolbox™

R2019a

Train to imitate existing controller

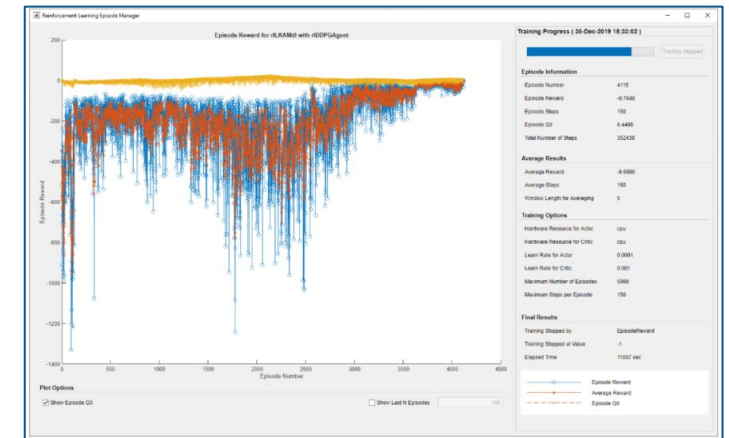


Imitate MPC Controller for Lane Keep Assist

Reinforcement Learning Toolbox™
Model Predictive Control Toolbox™

R2020a

Train from pretrained network



Train DDPG Agent with Pretrained Actor Network

Reinforcement Learning Toolbox™

R2020a

Design and deploy algorithms

Planning & control workflows

Motion
planning

Decision
logic

Longitudinal
controls

Lateral
controls

Perception workflows

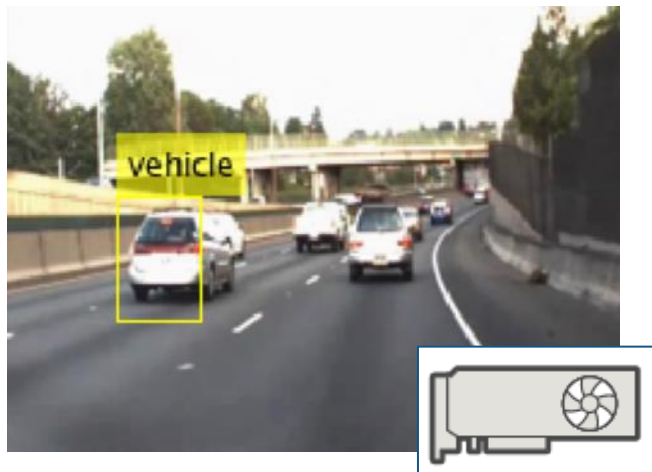
Detection

Tracking &
sensor fusion

Localization

Deploy deep learning networks

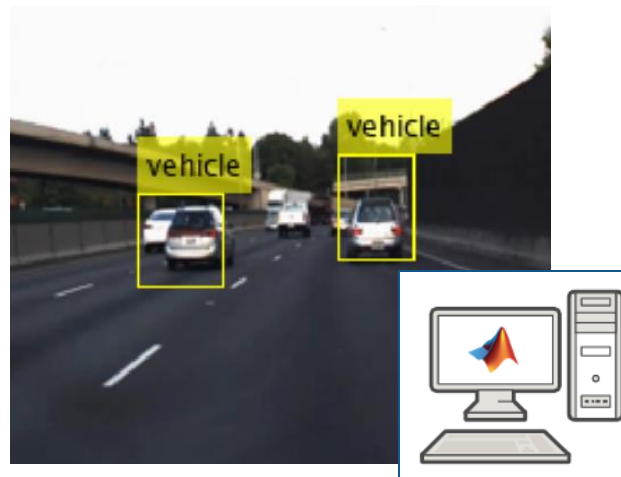
NVIDIA GPU



[Code Generation for Object Detection by Using Single Shot Multibox Detector](#)
 Deep Learning Toolbox™
 GPU Coder™

R2020a

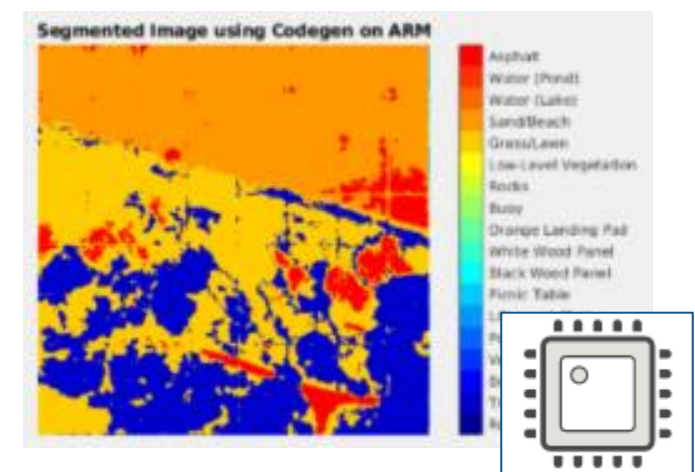
Intel MKL-DNN



[Generate C++ Code for Object Detection Using YOLO v2 and Intel MKL-DNN](#)
 Deep Learning Toolbox™
 MATLAB Coder®

R2019a

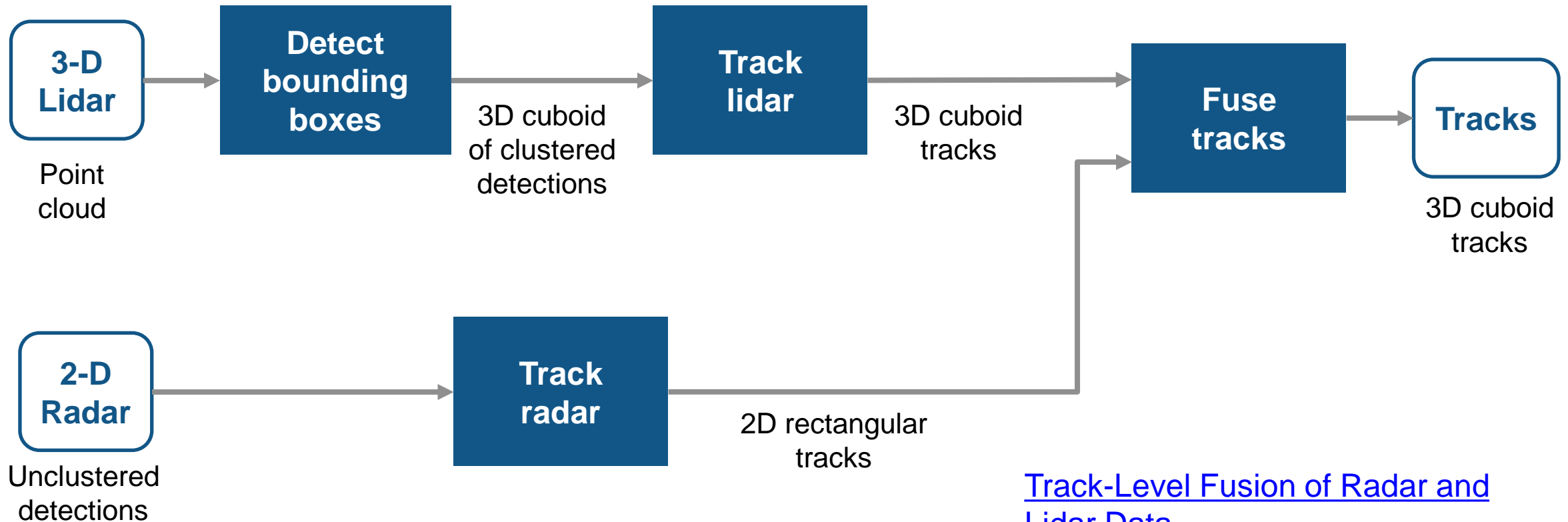
ARM



[Code Generation for Semantic Segmentation Application on ARM Neon](#)
 Deep Learning Toolbox™
 MATLAB Coder®

R2020a

Track-level Fusion of Radar and Lidar Data



[Track-Level Fusion of Radar and Lidar Data](#)

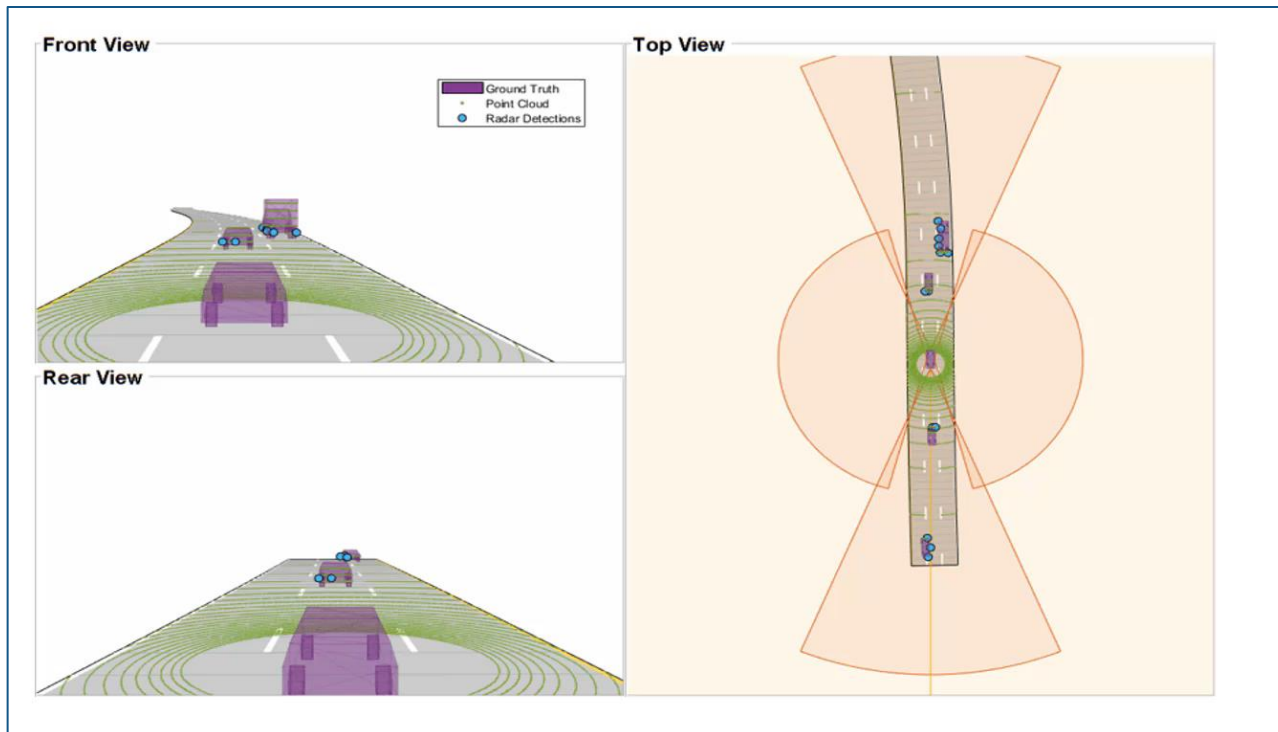
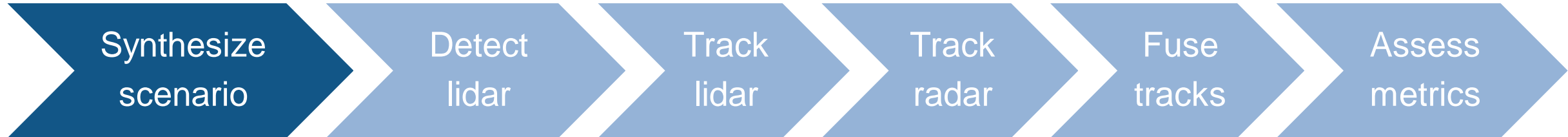
Automated Driving Toolbox™

Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™

R2020a

Fuse lidar point cloud with radar detections



- Create scene
- Add actors
- Add lidar point cloud sensor
- Add radar detection sensor

[Track-Level Fusion of Radar and Lidar Data](#)

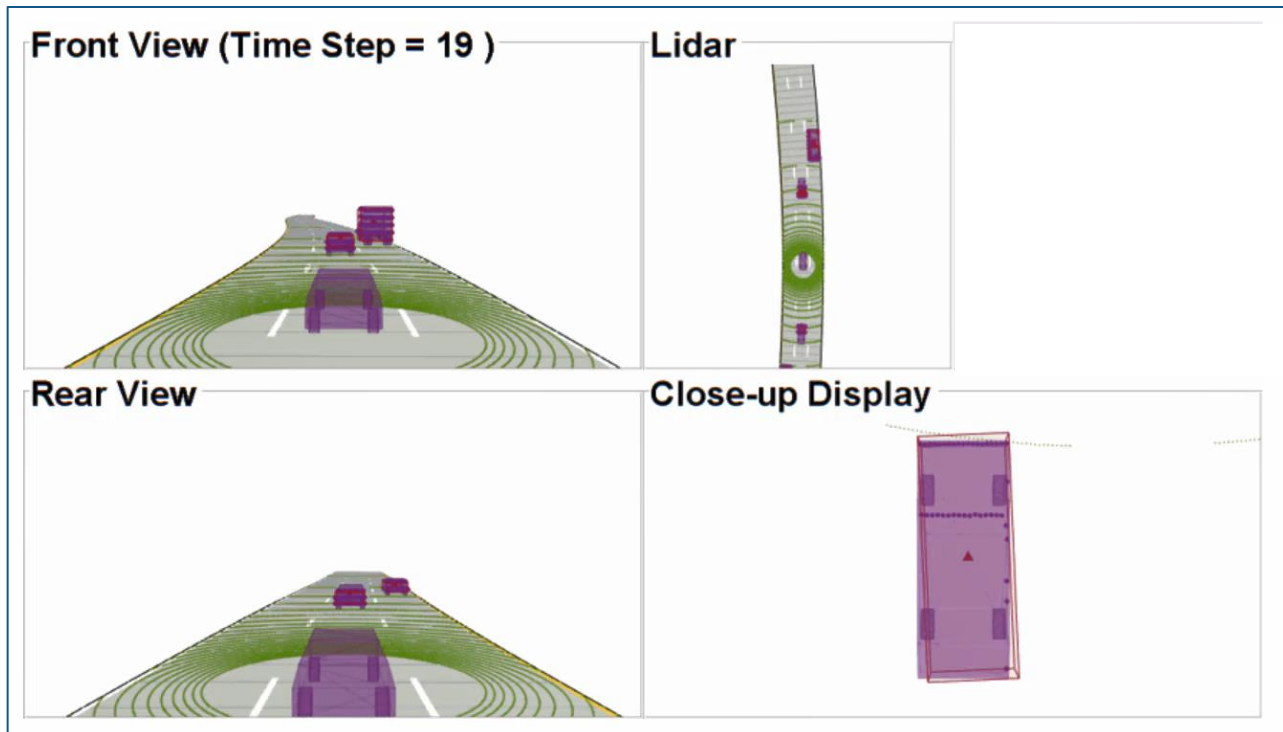
Automated Driving Toolbox™

Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™

R2020a

Fuse lidar point cloud with radar detections



- Remove ground plane
- Segment and cluster detections
- Fit bounding box to clusters

[Track-Level Fusion of Radar and Lidar Data](#)

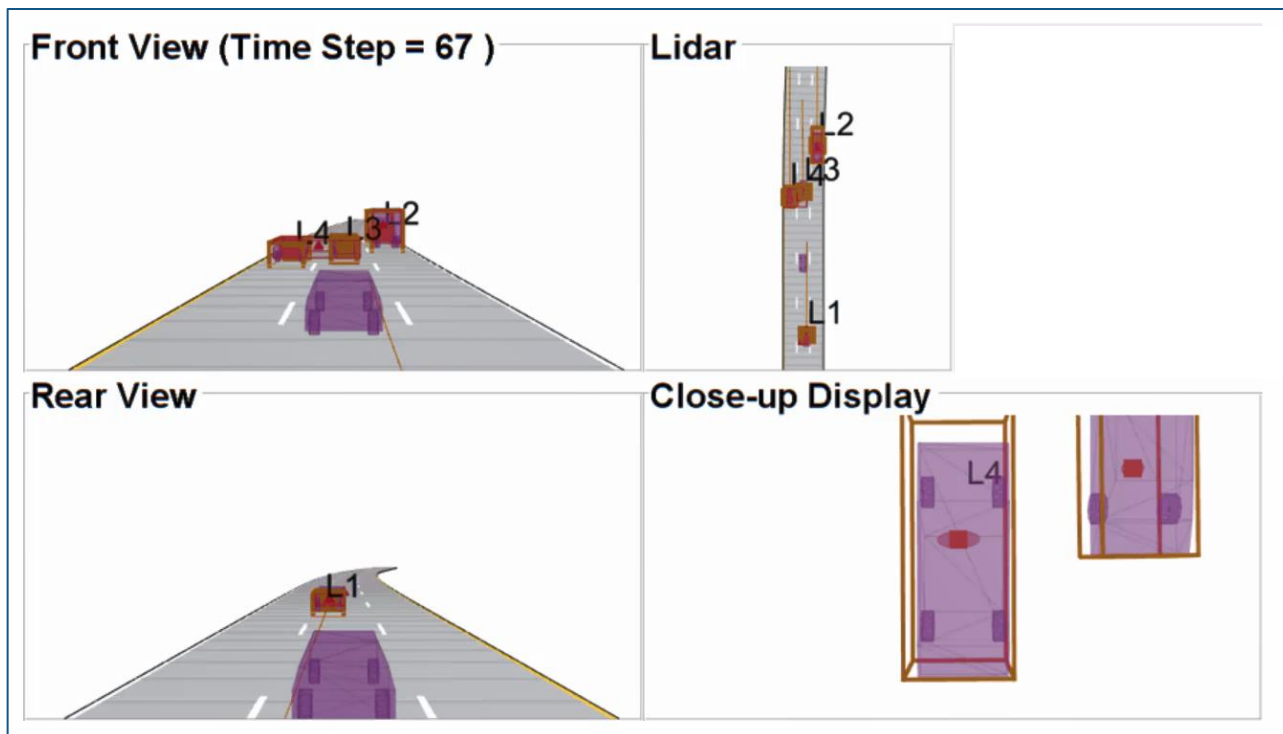
Automated Driving Toolbox™

Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™

R2020a

Fuse lidar point cloud with radar detections



- Design conventional joint probabilistic data association (JPDA) multi-object tracker
- Track vehicles during lane change with interacting multiple model unscented Kalman filter (IMM-UKF)

[Track-Level Fusion of Radar and Lidar Data](#)

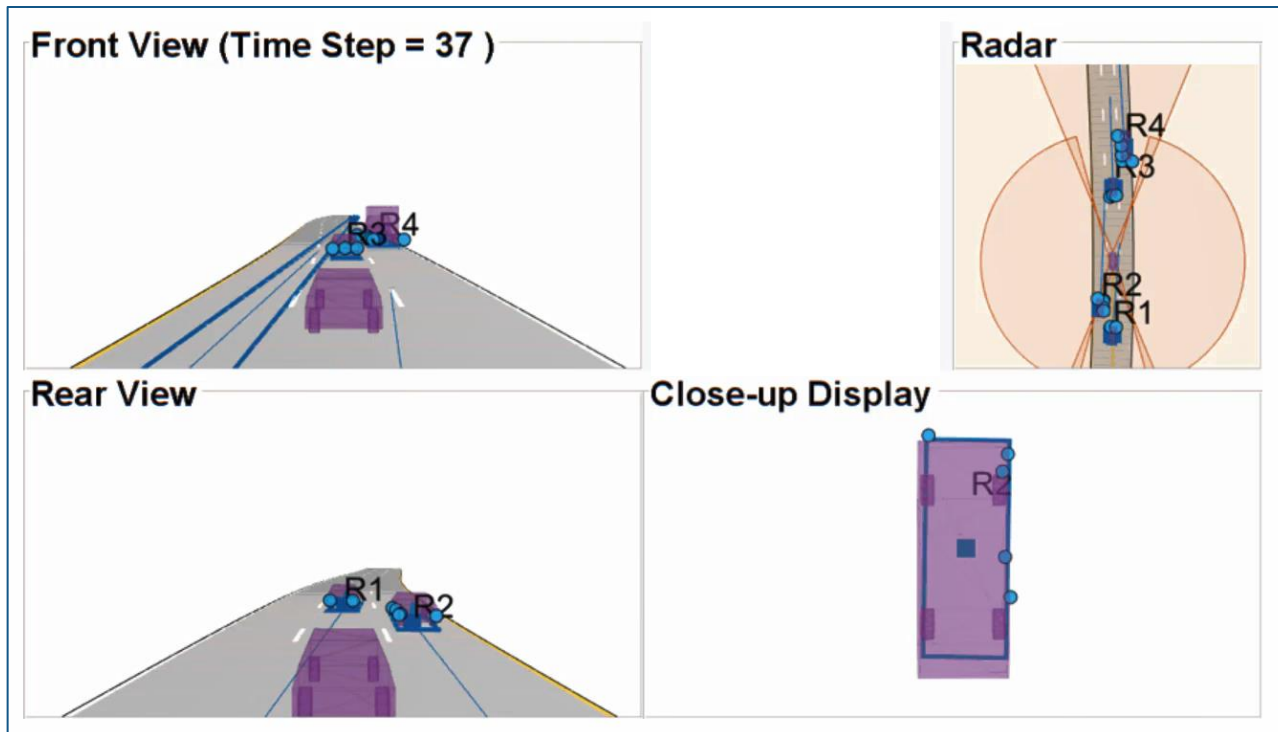
Automated Driving Toolbox™

Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™

R2020a

Fuse lidar point cloud with radar detections



- Design extended object tracker with Gaussian Mixture probability hypothesis density filter (GM-PHD)

Track-Level Fusion of Radar and Lidar Data

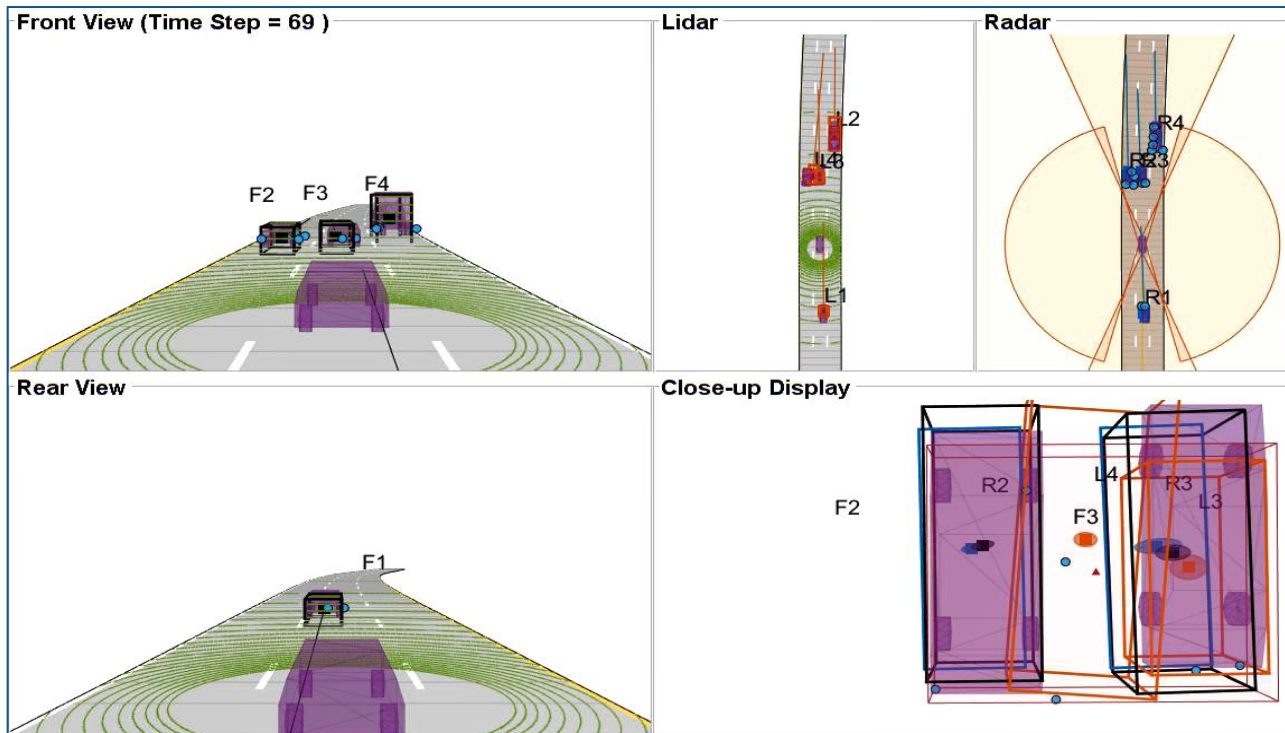
Automated Driving Toolbox™

Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™

R2020a

Fuse lidar point cloud with radar detections



- Design track level fusion
- Visualize

[Track-Level Fusion of Radar and Lidar Data](#)

Automated Driving Toolbox™

Computer Vision Toolbox™

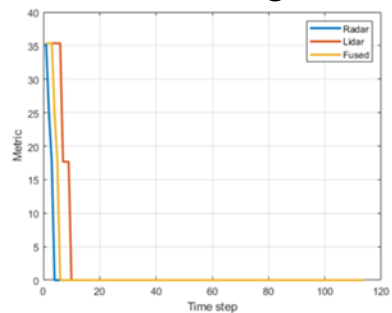
Sensor Fusion and Tracking Toolbox™

R2020a

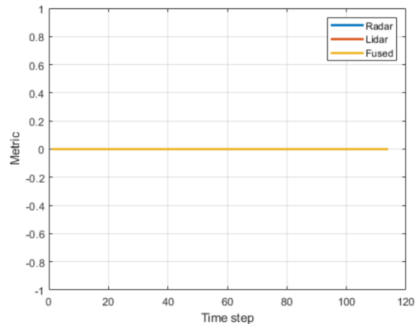
Fuse lidar point cloud with radar detections



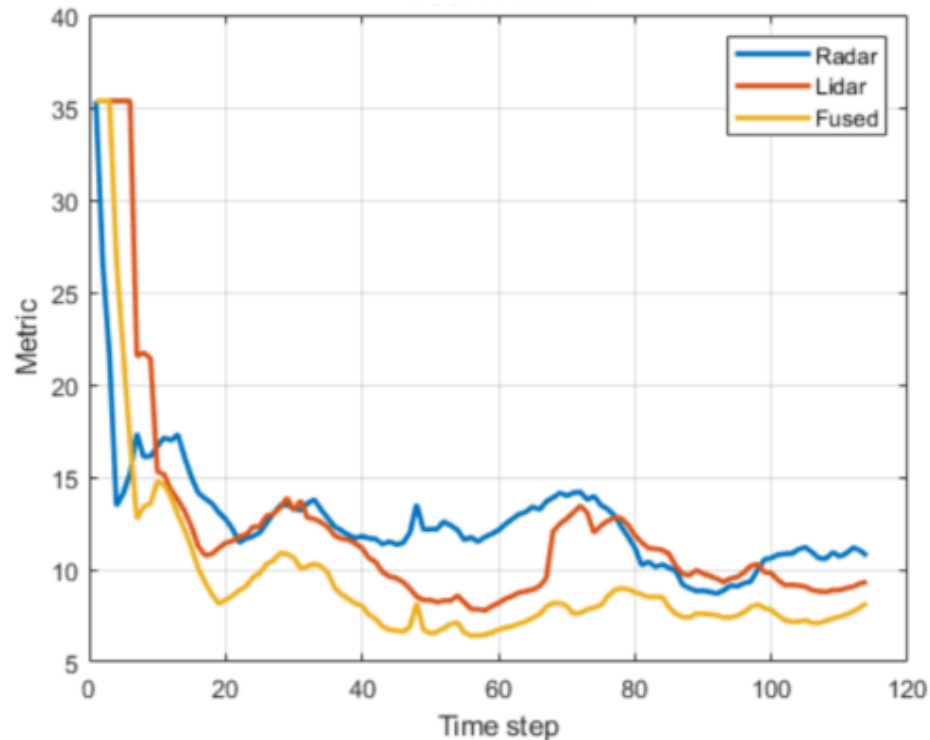
Missed Targets



False Tracks



GOSPA



- Assess missed tracks
- Assess false tracks
- Assess generalized optimal sub-pattern assignment metric (GOSPA)

[Track-Level Fusion of Radar and Lidar Data](#)

Automated Driving Toolbox™

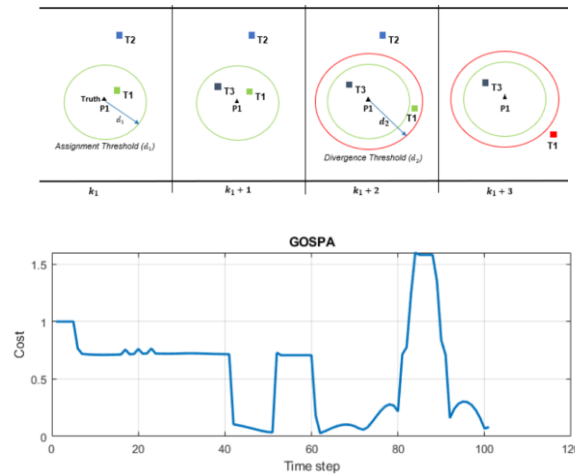
Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™

R2020a

Design object tracking and sensor fusion

Measure

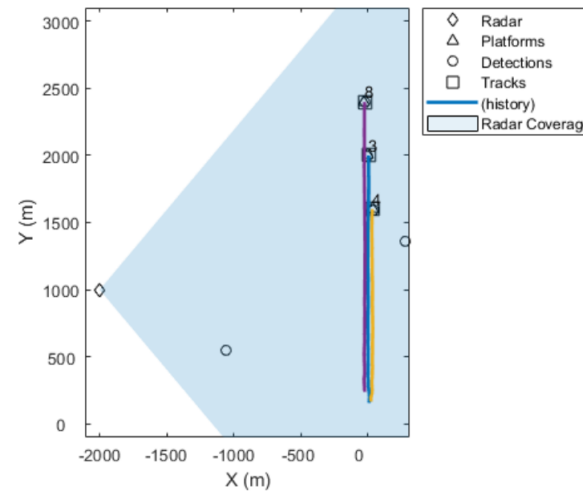


[Introduction to Tracking Metrics](#)

*Sensor Fusion and Tracking
Toolbox™*

R2020a

Tune

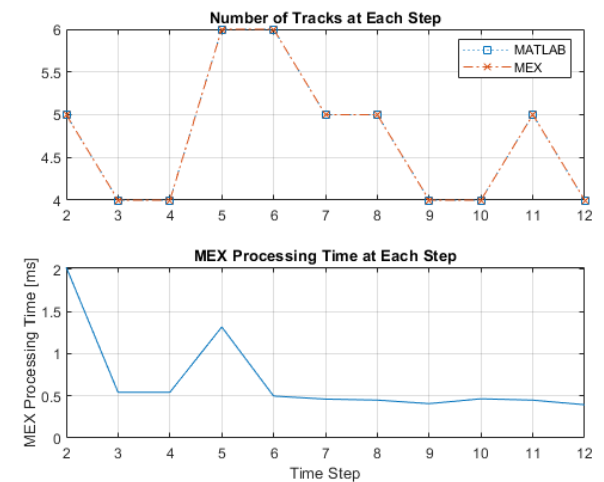


[Tuning a Multi-Object Tracker](#)

*Sensor Fusion and Tracking
Toolbox™*

R2020a

Generate code



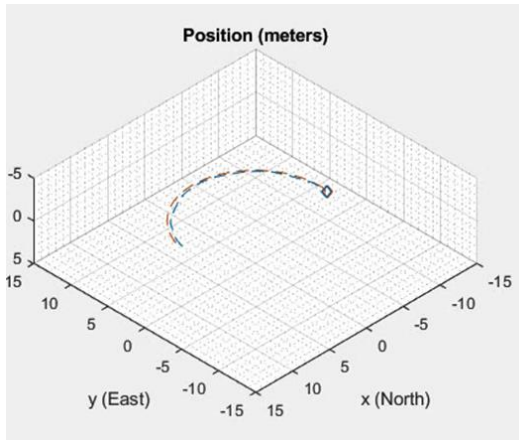
[Generate C Code for a Tracker](#)

*Sensor Fusion and Tracking
Toolbox™
MATLAB Coder®*

R2019a

Design localization algorithms

Inertial fusion (IMU & GPS)

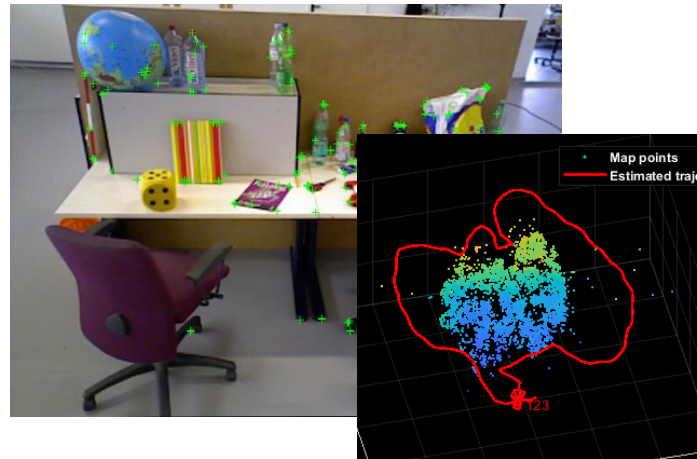


Estimate Position and Orientation of a Ground Vehicle

*Sensor Fusion and Tracking
Toolbox™*

R2019b

SLAM (Monocular camera)



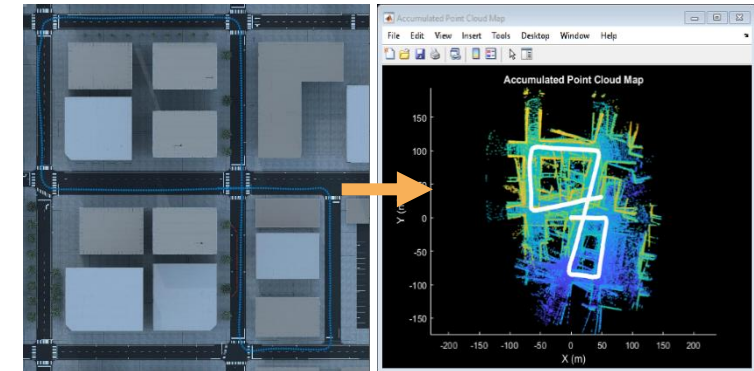
Monocular Visual Simultaneous Localization and Mapping

(SLAM)

Computer Vision Toolbox™

R2020a

SLAM (Lidar)



Design Lidar SLAM Algorithm using 3D Simulation Environment

Automated Driving Toolbox™

Computer Vision Toolbox™

Navigation Toolbox™

R2020a

Design and deploy algorithms

Planning & control workflows

Motion
planning

Decision
logic

Longitudinal
controls

Lateral
controls

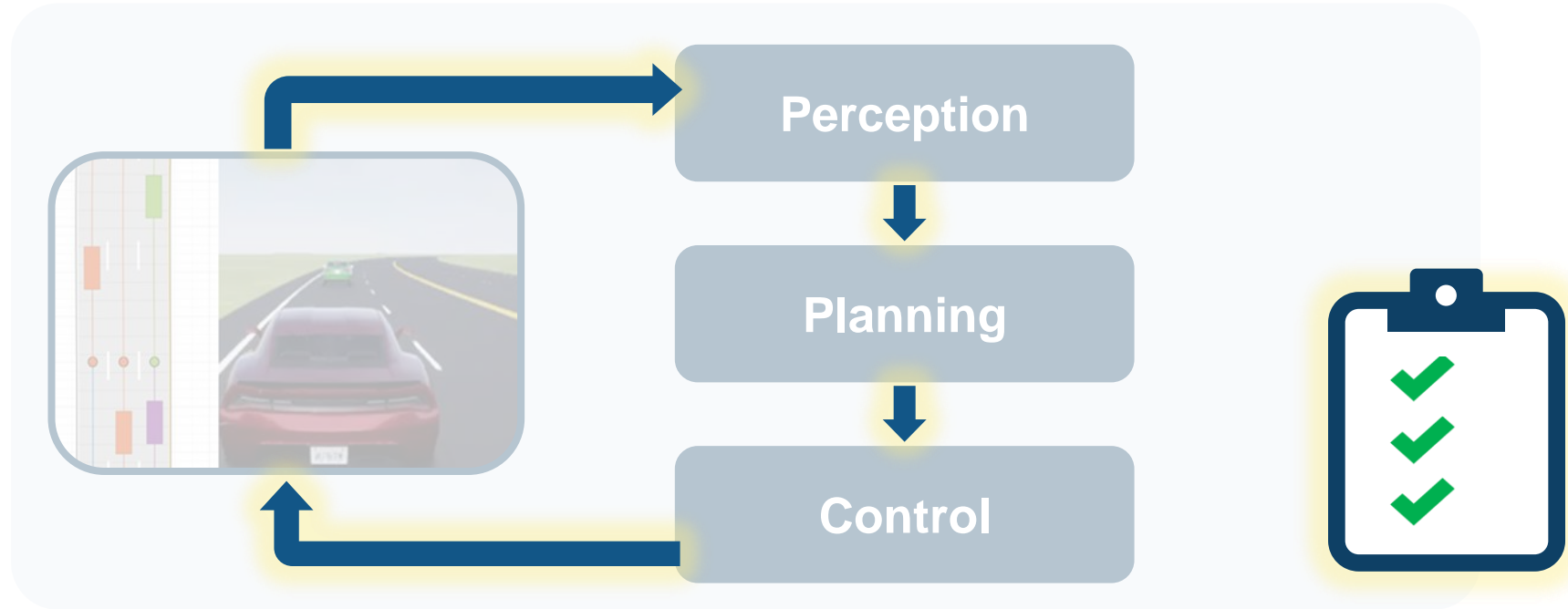
Perception workflows

Detection

Tracking &
sensor fusion

Localization

Some common questions from automated driving engineers



How can I
analyze & synthesize
scenarios?

How can I
design & deploy
algorithms?

How can I
integrate & test
systems?

Integrate and test systems

Integration workflows

MATLAB &
Simulink

C / C++
GPU

CAN
ROS

FMI
FMU

Python

...

Testing workflows

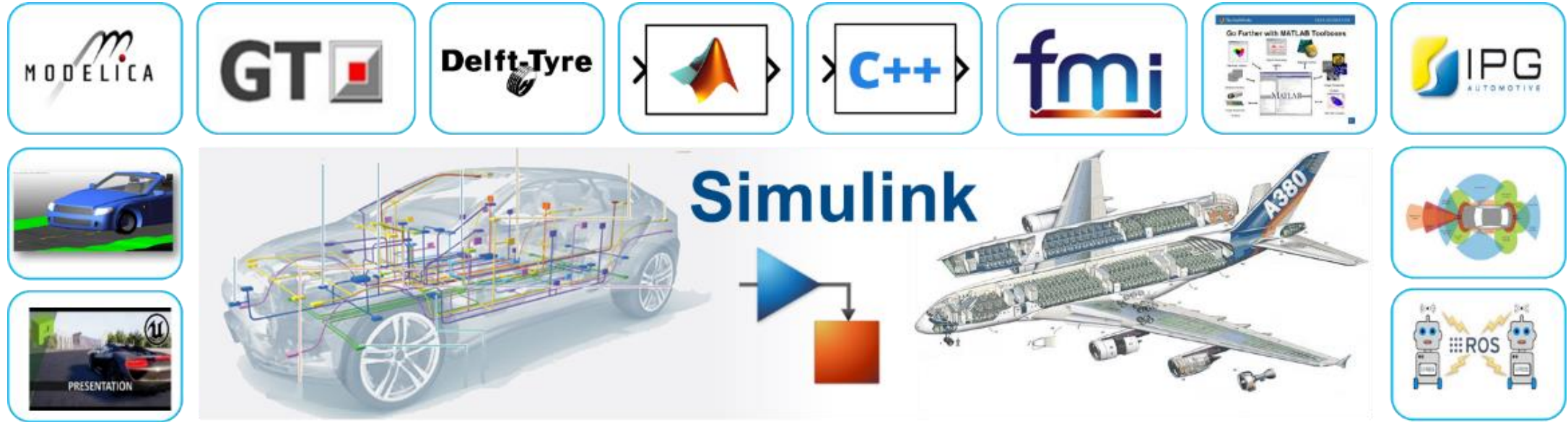
Requirements

Automation

Functional
assessment

Code
assessment

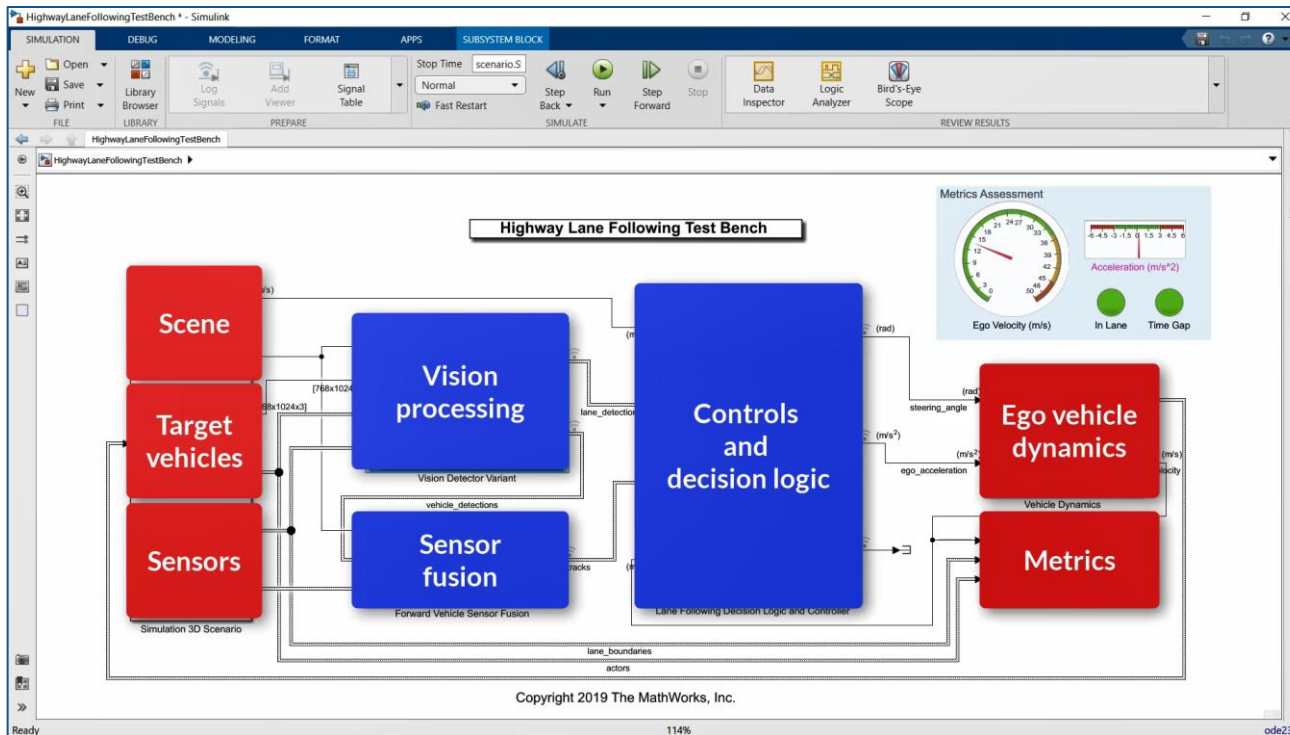
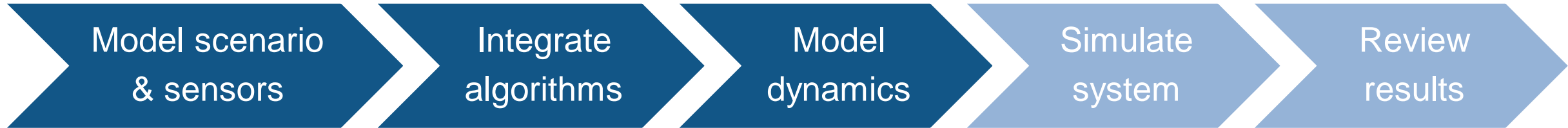
Integrate with hand code and other tools



Over 150 interfaces to 3rd party modeling and simulation tools



Integrate vision detection, sensor fusion, and controls

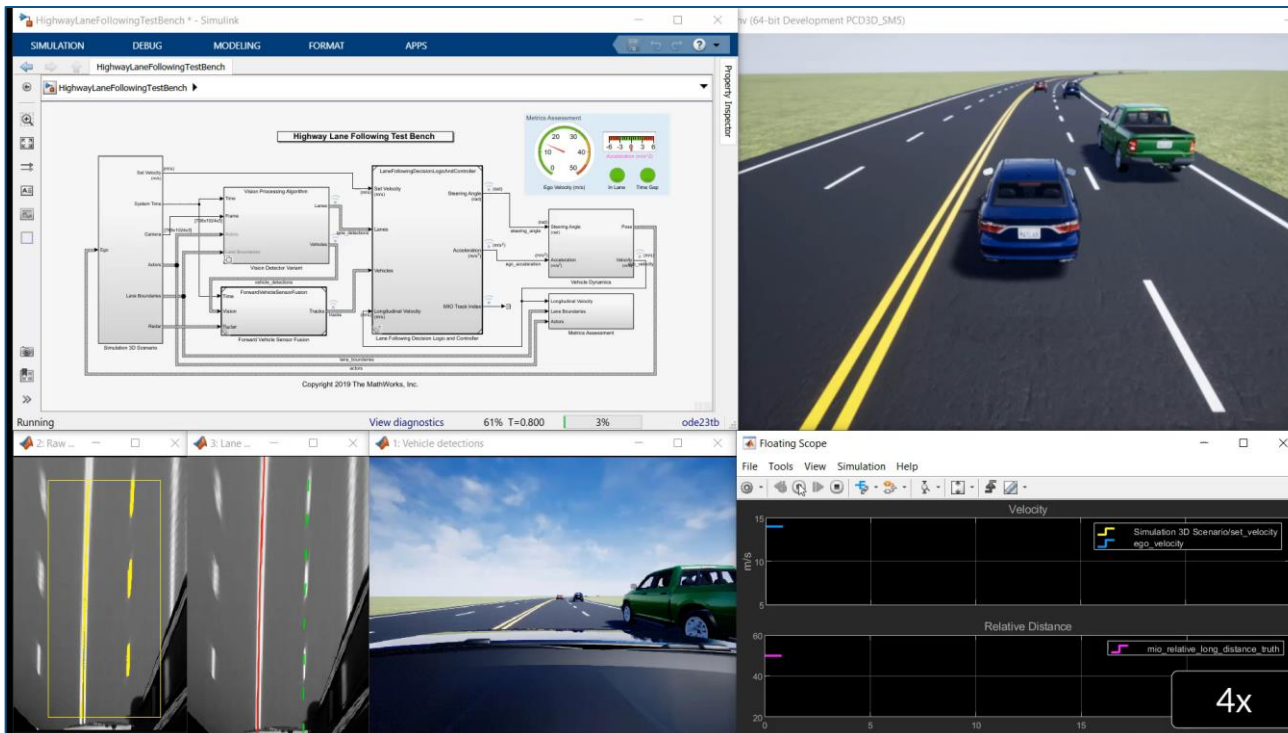
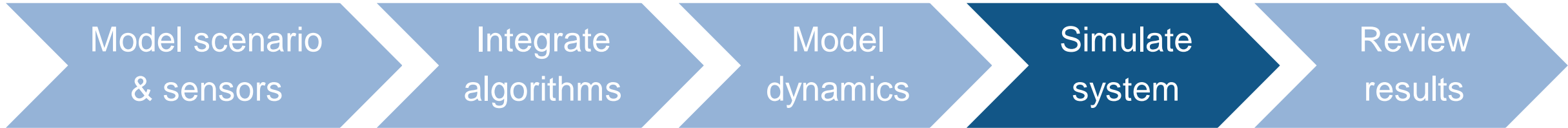


- Create Unreal Engine scene
- Specify target trajectories
- Model camera and radar sensors
- Model ego vehicle dynamics
- Specify system metrics

Highway Lane Following
Automated Driving Toolbox™
Model Predictive Control Toolbox™

Updated **R2020a**

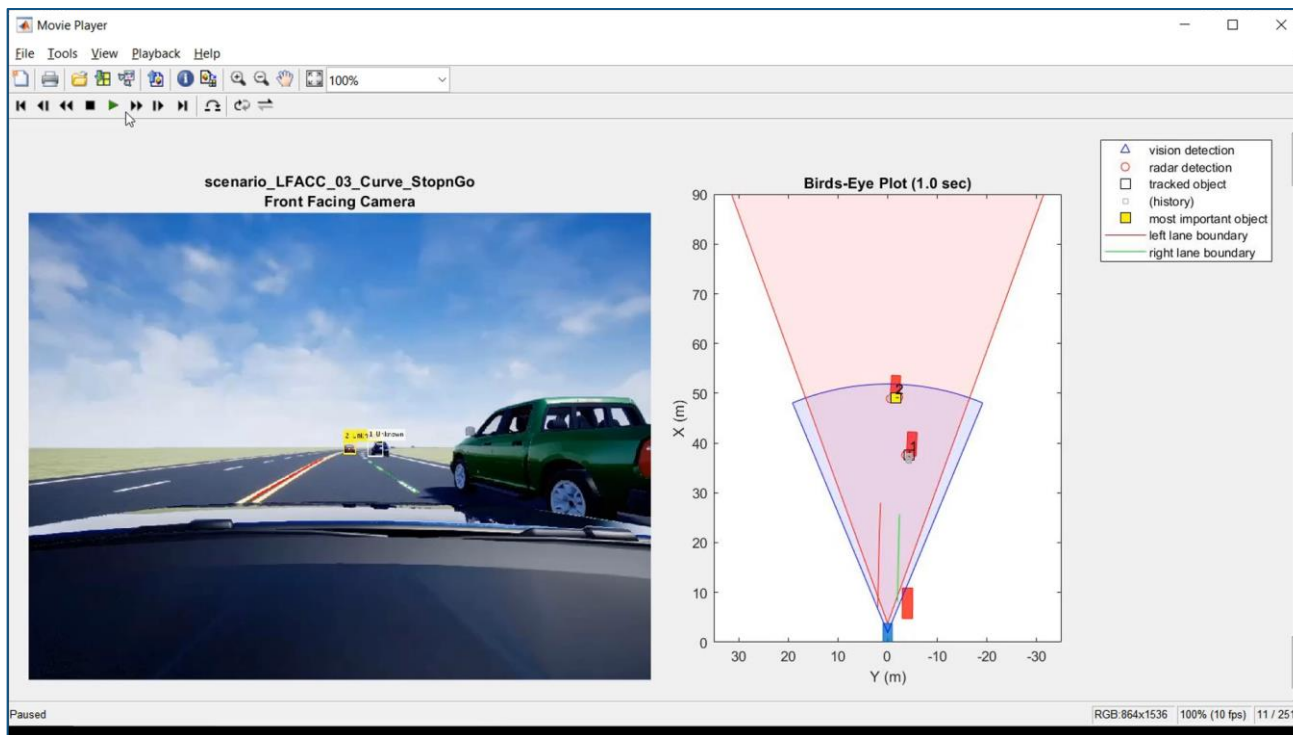
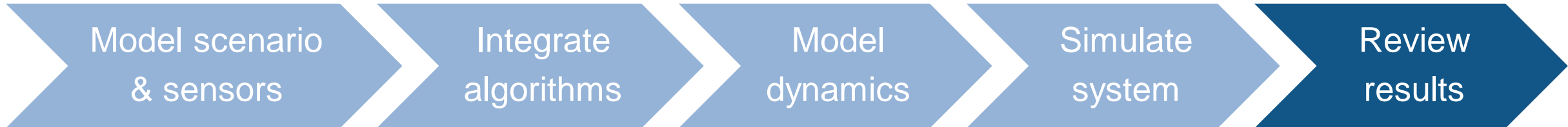
Integrate vision detection, sensor fusion, and controls



- Visualize system behavior with Unreal Engine
- Visualize lane detections
- Visualize vehicle detections
- Visualize control signals
- Log simulation data

[Highway Lane Following Automated Driving Toolbox™](#)
 Model Predictive Control Toolbox™
 Updated **R2020a**

Integrate vision detection, sensor fusion, and controls



- Plot logged simulation data
- Reuse visualizations from real-data workflows
- Generate video of results to share with other teams

[Highway Lane Following](#)

Automated Driving Toolbox™

Model Predictive Control Toolbox™

Updated

R2020a

Integrate and test systems

Integration workflows

MATLAB &
Simulink

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FMI
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...

Testing workflows

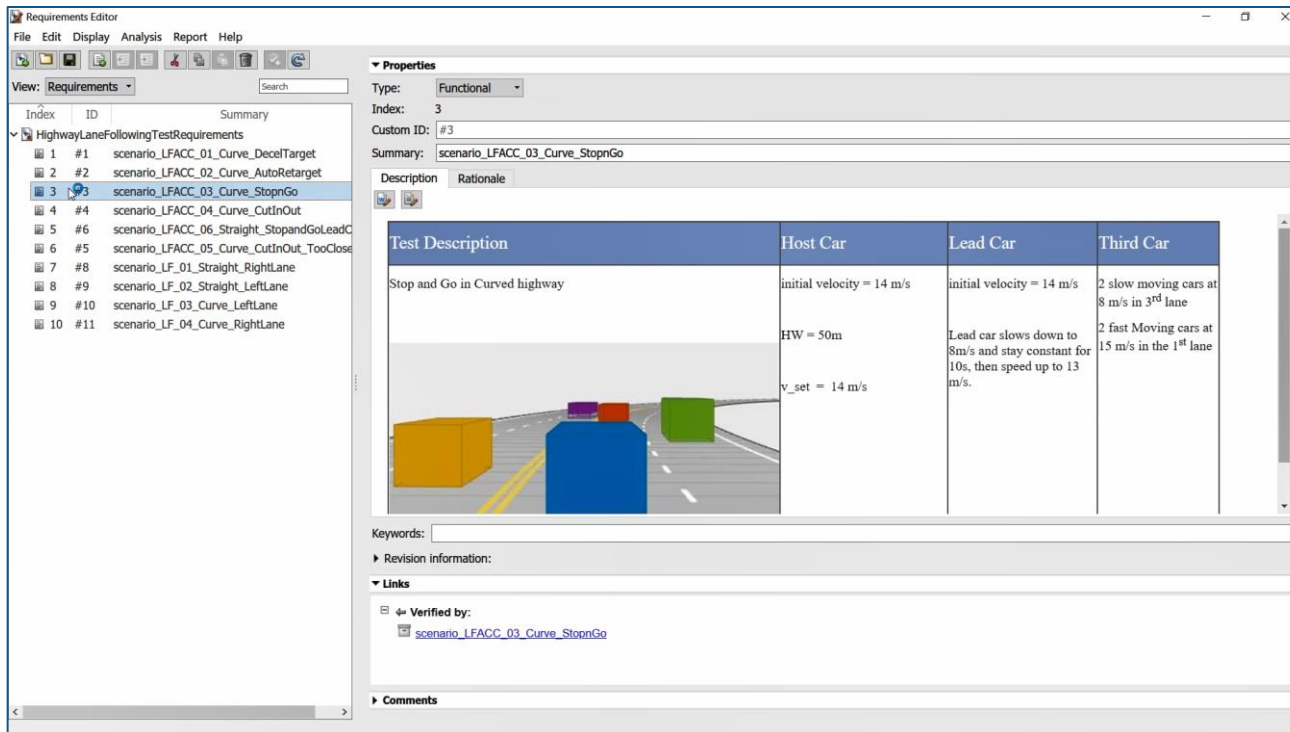
Requirements

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assessment

Code
assessment

Automate testing for highway lane following perception and controls



- Author and associate requirements and scenarios

[Automate Testing for Highway Lane Following Automated Driving Toolbox™](#)
[Model Predictive Control Toolbox™](#)
[Simulink Test™](#)
[Simulink Requirements™](#)
[Simulink Coverage™](#)

R2020a

Automate testing for highway lane following perception and controls

Link to requirements

Automate tests

Assess functionality

Integrate code

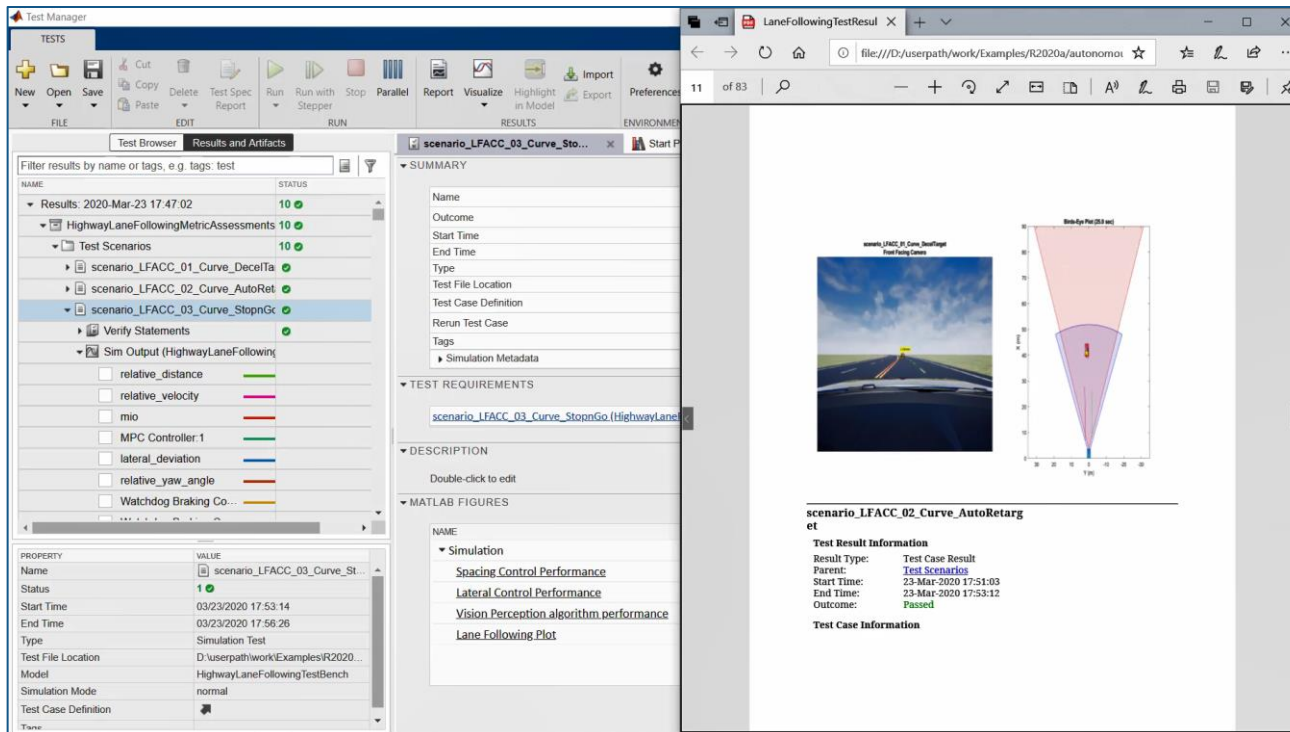
Assess code

The screenshot displays the MathWorks Test Manager and Simulink environments. The Test Manager window on the left shows a list of test scenarios under 'HighwayLaneFollowingMetricAssessments', including 'scenario_LFACC_03_Curve_StopnGo'. The Simulink window on the right shows a Simulink model titled 'Highway Lane Following Test Bench' with various blocks and a 'Metric Assessment' gauge.

- Automate test execution and reporting
- Execute simulations in parallel

[Automate Testing for Highway Lane Following Automated Driving Toolbox™ Model Predictive Control Toolbox™ Simulink Test™ Simulink Requirements™ Simulink Coverage™](#)
R2020a

Automate testing for highway lane following perception and controls

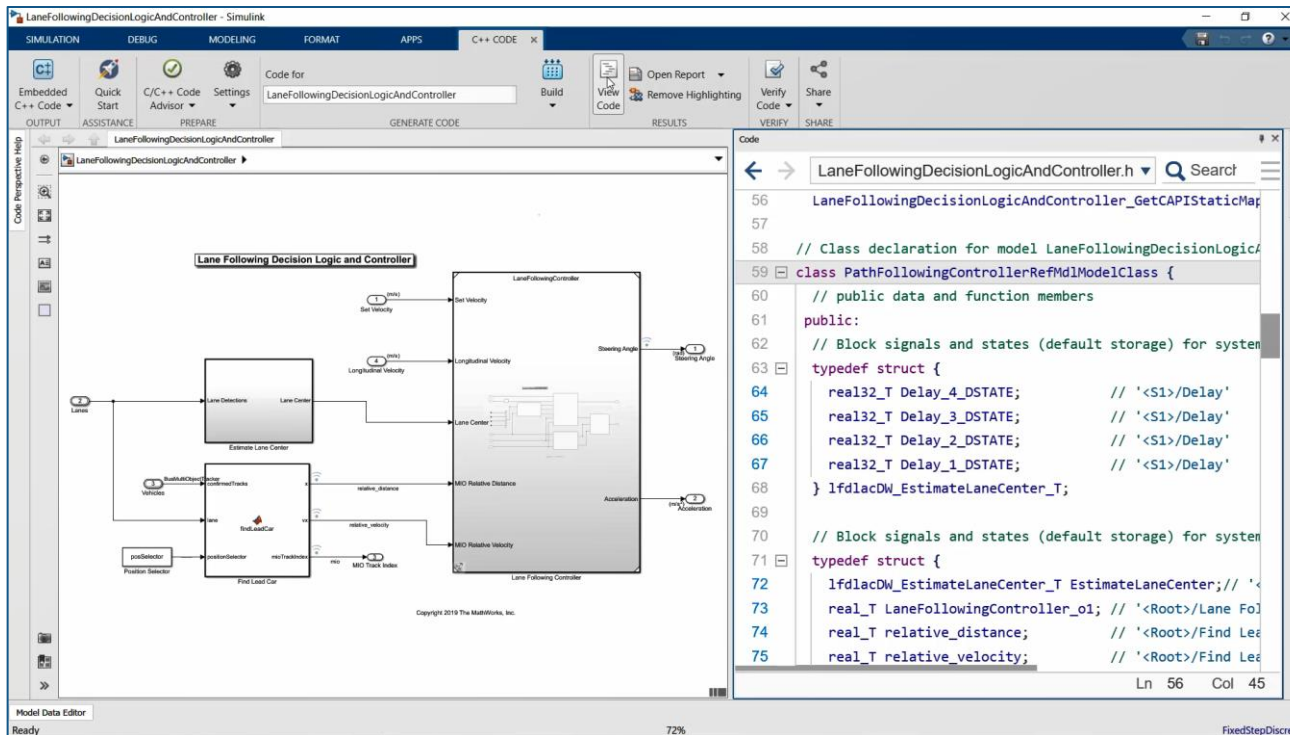


- Assess system metrics
- Assess lane detection metrics

[Automate Testing for Highway Lane Following Automated Driving Toolbox™ Model Predictive Control Toolbox™ Simulink Test™ Simulink Requirements™ Simulink Coverage™](#)

R2020a

Automate testing for highway lane following perception and controls

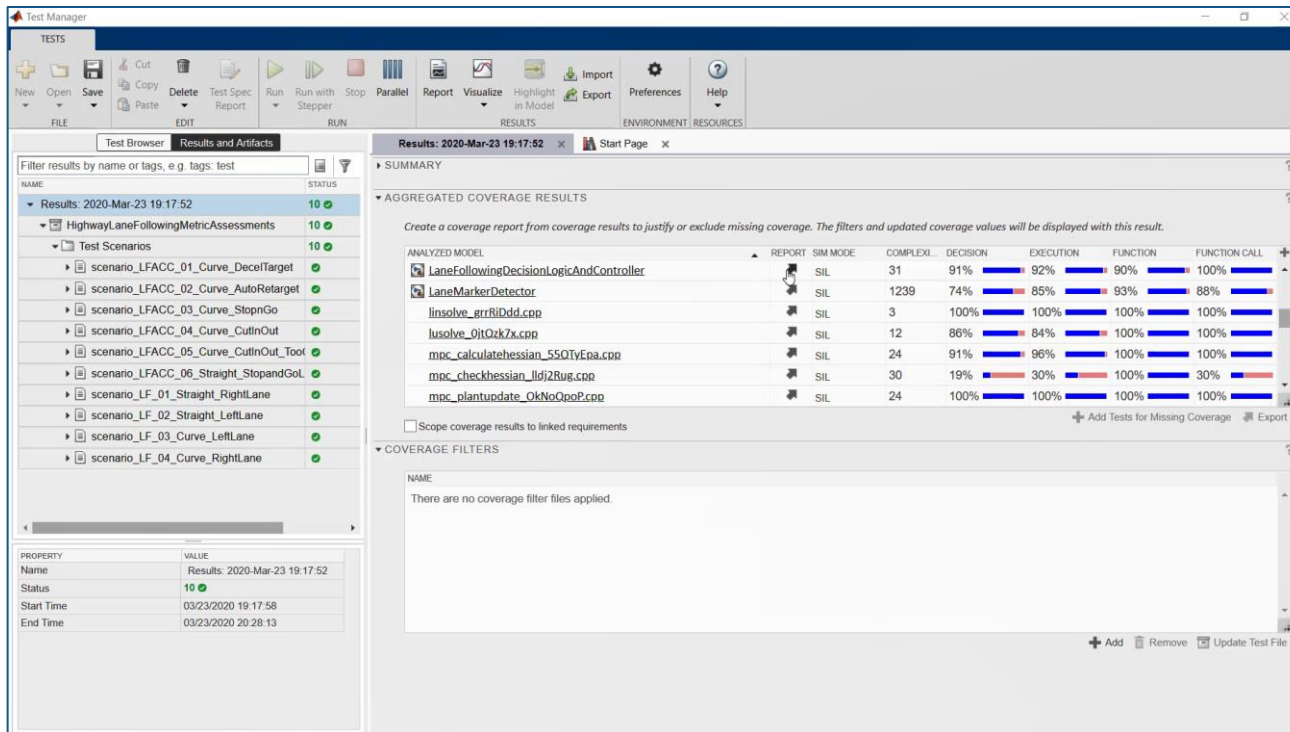


- Generate algorithm code
- Test with Software-in-the-Loop (SIL) simulation
- Workflow could be extended to test hand coded algorithms

[Automate Testing for Highway Lane Following Automated Driving Toolbox™ Model Predictive Control Toolbox™ Simulink Test™ Simulink Requirements™ Simulink Coverage™](#)

R2020a

Automate testing for highway lane following perception and controls



- Assess functionality
- Assess code coverage

[Automate Testing for Highway Lane Following Automated Driving Toolbox™ Model Predictive Control Toolbox™ Simulink Test™ Simulink Requirements™ Simulink Coverage™](#)

R2020a

Integrate and test systems

Integration workflows

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Python

...

Testing workflows

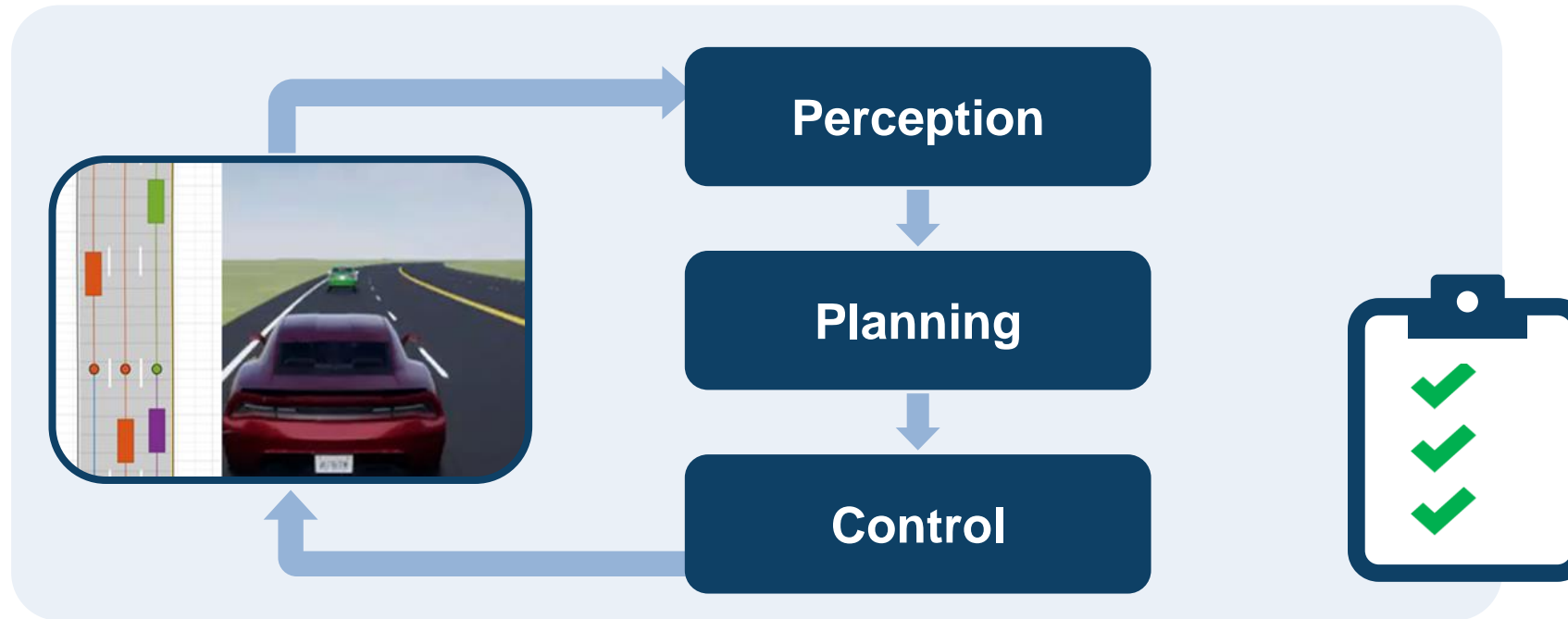
Requirements

Automation

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Code
assessment

MATLAB and Simulink enable automated driving engineers to...



analyze & synthesize
scenarios

design & deploy
algorithms

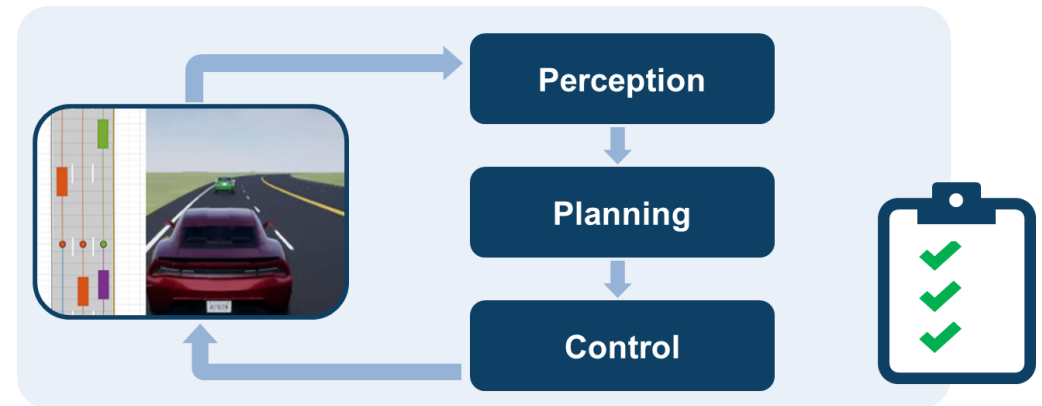
integrate & test
systems

Poll and contact details

Which workflows are most important to you?

- A. Synthesize scenes
- B. Synthesize sensor data
- C. Design perception
- D. Design planning
- E. Design controls
- F. Generate C code
- G. Generate C++ code
- H. Integrate hand code
- I. Automate testing

Provide your name and email address in the poll if you would like us to follow-up with you



Contact me at:

mcorless@mathworks.com