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?

Diagram showing the process of perception, planning, and control for automated driving 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™

**ROS**

ROS 2.0
Work with Specialized ROS Messages
ROS Toolbox™

**HERE HD Live Map**
Use HERE HD Live Map Data to Verify Lane Configurations
Automated Driving Toolbox™
Visualize vehicle data

**Detections**

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

**Images**

Annotate Video Using Detections in Vehicle Coordinates
*Automated Driving Toolbox™*

**Maps**

Display Data on OpenStreetMap Basemap
*Automated Driving Toolbox™*
Label camera and lidar data

- 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

- **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

- 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

Real-world data workflows
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Enables open loop workflows

Synthetic scenario workflows
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### Synthesize scenarios to test algorithms and systems

<table>
<thead>
<tr>
<th>Scenes</th>
<th>Cuboid</th>
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<tr>
<td><img src="image.png" alt="Image" /></td>
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## Synthesize scenarios to test algorithms and systems

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</table>
| 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

- 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

Define trajectory
Model monocular camera
Display image
Display depth
Display labels

Visualize Depth and Semantic Segmentation Data in 3D 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™

 Trajectories

Specify Vehicle Trajectories for 3D Simulation
 Automated Driving Toolbox™

Customize scenes

Customize 3D Scenes for Automated Driving
 Automated Driving Toolbox™
Design 3D scenes for automated driving simulation

New base product
Does not require MATLAB
Design scenes with road, marking, and prop assets

- Roads and markings
- Traffic signals
- Guard rails
- Trees
- Signs
- Elevation data
Design scenes and export to driving simulator

- 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

- 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)
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

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
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)

Lane Keep Assist (Lateral control)

Lane Following (longitudinal + lateral control)
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™*

**Deploy to ROS 2 node**

Automated Parking Valet with ROS 2 in Simulink

*Automated Driving Toolbox™
ROS Toolbox™
Embedded Coder®*

**Planner & Controller = Nonlinear MPC**

Parking Valet using Nonlinear Model Predictive Control

*Automated Driving Toolbox™
Model Predictive Control Toolbox™
Navigation Toolbox™*
Design controls with reinforcement learning

**Train new network**

Train DQN Agent for Lane Keeping Assist
Reinforcement Learning Toolbox™

**Train to imitate existing controller**

Imitate MPC Controller for Lane Keep Assist
Model Predictive Control Toolbox™

**Train from pretrained network**

Train DDPG Agent with Pretrained Actor Network
Reinforcement Learning Toolbox™
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

Image of a highway with a vehicle highlighted, NVIDIA GPU icon

Code Generation for Object Detection by Using Single Shot Multibox Detector
Deep Learning Toolbox™
GPU Coder™

Intel MKL-DNN

Image of a highway with vehicles highlighted, Intel MKL-DNN icon

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

ARM

Image of a segmented image, ARM icon

Code Generation for Semantic Segmentation Application on ARM Neon
Deep Learning Toolbox™
MATLAB Coder®
Track-level Fusion of Radar and Lidar Data

3-D Lidar

<table>
<thead>
<tr>
<th>Detect bounding boxes</th>
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</thead>
<tbody>
<tr>
<td>3D cuboid of clustered detections</td>
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</tbody>
</table>

Point cloud

2-D Radar

<table>
<thead>
<tr>
<th>Track radar</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D rectangular tracks</td>
</tr>
</tbody>
</table>

Unclustered detections

Track radar

<table>
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<tr>
<th>Track lidar</th>
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Fuse tracks

<table>
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<th>Tracks</th>
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<td>3D cuboid tracks</td>
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</table>

Track-Level Fusion of Radar and Lidar Data

Automated Driving Toolbox™

Computer Vision Toolbox™

Sensor Fusion and Tracking Toolbox™
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™
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™
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™
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™
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™
Fuse lidar point cloud with radar detections

- 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™
Design object tracking and sensor fusion

**Measure**

- Introduction to Tracking Metrics
  - Sensor Fusion and Tracking Toolbox™

**Tune**

- Tuning a Multi-Object Tracker
  - Sensor Fusion and Tracking Toolbox™

**Generate code**

- Generate C Code for a Tracker
  - Sensor Fusion and Tracking Toolbox™
  - MATLAB Coder®
Design localization algorithms

Inertial fusion (IMU & GPS)

- Estimate Position and Orientation of a Ground Vehicle
  - Sensor Fusion and Tracking Toolbox™

SLAM (Monocular camera)

- Monocular Visual Simultaneous Localization and Mapping (SLAM)
  - Computer Vision Toolbox™

SLAM (Lidar)

- Design Lidar SLAM Algorithm using 3D Simulation Environment
  - Automated Driving Toolbox™
  - Computer Vision Toolbox™
  - Navigation Toolbox™
Design and deploy algorithms

Planning & control workflows
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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

Model scenario & sensors | Integrate algorithms | Model dynamics | Simulate system | Review results

- 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

- Model scenario & sensors
- Integrate algorithms
- Model dynamics
- Simulate system
- Review results

- 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

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Testing workflows

- Requirements
- Automation
- Functional 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

- 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™
Automate testing for highway lane following perception and controls

Link to requirements
Automate tests
Assess functionality
Integrate code
Assess code

- 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 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
- MATLAB & Simulink
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Testing workflows
- Requirements
- Automation
- Functional assessment
- 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