What’s New in Automated Driving with MATLAB and Simulink

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MathWorks

AUTOMOTIVE CONFERENCE 2020
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

Synthetic scenario workflows
- Create scenes
- Model actors
- Model sensors

Enables open loop workflows
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**

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 sensor data with Ground Truth Labeler App

- Interactively label sensor data
  - Rectangular region of interest (ROI)
  - Polyline ROI
  - Pixel ROI (semantic segmentation)
  - Cuboid (lidar)
  - Scenes
- Automate labeling with built-in detection and tracking algorithms
- Register custom automation algorithms
- Register custom visualizations
- Export labels for verification or training

Ground Truth Labeler
Automated Driving Toolbox™
Updated R2020a
Analyze and synthesize scenarios

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Enables open loop workflows

Synthetic scenario workflows

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Enables open loop and closed loop workflows
### Synthesize scenarios to test algorithms and systems

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<th>Scenes</th>
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<th>Unreal Engine</th>
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<td><img src="image" alt="Cuboid Scene" /></td>
<td><img src="image" alt="Unreal Engine Scene" /></td>
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<td>Testing</td>
<td>Controls, sensor fusion, planning</td>
<td>Controls, sensor fusion, planning, perception</td>
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<td>Sensing</td>
<td>- Probabilistic vision (detection list)</td>
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<td>- Probabilistic lane (detection list)</td>
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<td>- Lidar (point cloud)</td>
<td>- Lidar (point cloud)</td>
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</table>
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 actors in driving scenarios

Vehicle dynamics

Three-Axle Tractor Towing a Trailer
Vehicle Dynamics Blockset™

Scenario variations

Create Driving Scenario Variations Programmatically
Automated Driving Toolbox™

Intelligent vehicles

Automate Control of Intelligent Vehicles by Using Stateflow Charts
Automated Driving Toolbox™
Stateflow®
Synthesize Unreal Engine driving scenarios

Prebuilt scenes

3D Simulation for Automated Driving
Automated Driving Toolbox™

Customize scenes

Customize 3D Scenes for Automated Driving
Automated Driving Toolbox™

Custom messages

Send and Receive Double-Lane Change Scene Data
Vehicle Dynamics Blockset™
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
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™

Visualization

Visualize 3D Simulation Sensor Coverages and Detections
Automated Driving Toolbox™
Design 3D scenes for automated driving simulation

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

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

Exporting to CARLA
RoadRunner™

Update 1
Design scenes with hundreds of premade assets

- Road and highway signs
- Traffic signals
- Road surface markings
- Trees
- Barriers
- Road damage textures
  - Cracks, oil spills

Asset Library
RoadRunner™ Asset Library
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
  - VIRES Virtual Test Drive, Metamoto
  - IPG Carmaker, Cognata, Baidu Apollo
  - Tesis Dynaware, TaSS PreScan
  - Universal Scene Description (USD)
Import, visualize, and edit OpenDRIVE files

- 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
Integrate RoadRunner with MATLAB and Simulink workflows

RoadRunner
- Export scene description (.FBX, .XML)
- Export OpenDRIVE (.XODR)

Unreal Engine
- Import to game

MATLAB & Simulink
- Connect to game
- Import to driving scenario
- Simulink model
Get started designing scenes by watching tutorial videos

- Add roads and junctions
- Add lane markings
- Add traffic signals
- Add traffic signs

https://www.mathworks.com/videos/search.html?q=roadrunner

RoadRunner™
Analyze and synthesize scenarios

**Real-world data workflows**
- Access
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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)

Adaptive Cruise Control with Sensor Fusion
Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder®

Lane Keeping Assist with Lane Detection
Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder®

Lane Following Control with Sensor Fusion
Model Predictive Control Toolbox™
Automated Driving Toolbox™
Embedded Coder®
Design planning and controls for highway lane change

- Specify road and target vehicle trajectories for scenario in MATLAB
- Read scenario from Simulink
- Visualize open loop trajectories with Driving Scenario Designer

Lane Change for Highway Driving
Navigation Toolbox™
Model Predictive Control Toolbox™
Automated Driving Toolbox™
Updated R2020a
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

Visualize with Unreal Engine

Deploy to ROS 2 node

Automated Parking Valet with Simulink

Automated Driving Toolbox™

Automated Parking Valet Using 3D Simulation

Automated Driving Toolbox™

Automated Parking Valet with ROS 2 in Simulink

Automated Driving Toolbox™

ROS Toolbox™

Embedded Coder®
Design parking planning and controls with Model Predictive Control

Planner = RRT
Controller = MPC

Parallel Parking using RRT Planner and MPC Tracking Controller
Automated Driving Toolbox™
Model Predictive Control Toolbox™
Navigation Toolbox™

Planner & Controller = Nonlinear MPC

Parallel Parking using Nonlinear Model Predictive Control
Automated Driving Toolbox™
Model Predictive Control Toolbox™
Navigation Toolbox™

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™
  - Train DDPG Agent with Pretrained Actor Network
    - Reinforcement Learning Toolbox™

- **Train to imitate existing controller**
  - Imitate MPC Controller for Lane Keep Assist
    - Reinforcement Learning Toolbox™
    - 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
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Perception workflows
- Detection
- Tracking & sensor fusion
- Localization
Design detectors and classifiers with deep learning

- SSD
- YOLO v3
- PointNet

Object Detection Using SSD
Deep Learning
Computer Vision Toolbox™
Deep Learning Toolbox™

Object Detection Using YOLO v3
Deep Learning
Computer Vision Toolbox™
Deep Learning Toolbox™

Point Cloud Classification Using PointNet
Deep Learning
Computer Vision Toolbox™
Deep Learning Toolbox™

R2020a
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

3-D Lidar

- Detect bounding boxes
  - 3D cuboid of clustered detections

2-D Radar

- Track radar
  - 2D rectangular tracks

Track-lidar

- 3D cuboid tracks

Fuse tracks

3D cuboid tracks

Tracks

Point cloud

Unclustered detections

2

D

Radar

3

D

Lidar

Detect bounding boxes

Track lidar

Fuse tracks

Tracks

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

- 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

Introduction to Tracking Metrics
Sensor Fusion and Tracking Toolbox™

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

Generate C Code for a Tracker
Sensor Fusion and Tracking Toolbox™
MATLAB Coder®
Estimate orientation and position with inertial sensor fusion

**Estimate Orientation through Inertial Sensor Fusion**

Sensor Fusion and Tracking Toolbox™

**Estimate Position and Orientation of a Ground Vehicle**

Sensor Fusion and Tracking Toolbox™

**Estimate Position and Orientation of a Ground Vehicle**

Sensor Fusion and Tracking Toolbox™

**IMU**

**IMU**

**IMU + GPS**
Design SLAM (Simultaneous Localization and Mapping)

**Monocular camera**

**Lidar** (real data)

**Lidar** (synthetic data)

**Monocular Visual Simultaneous Localization and Mapping**
*Computer Vision Toolbox™*

**Build a Map from Lidar Data Using SLAM**
*Automated Driving Toolbox™*  
*Computer Vision Toolbox™*  
*Navigation Toolbox™*

**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
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- 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++
- CAN
- ROS
- FMI
- FMU
- Python
- ...

Testing workflows
- Requirements
- Automation
- Functional assessment
- Code assessment
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

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

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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™
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

- 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™
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
Which workflows are most important to you?

- Synthesize scenes
- Synthesize Sensor data
- Design Perception
- Design Planning
- Design Controls
- Generate C code
- Generate C++ code
- Integrate hand code
- Automate Testing

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

Please contact us with questions

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