MATLAB EXPO 2019

Entwurf und Simulation von Systemen im Bereich des automatisierten Fahrens mit MATLAB und Simulink

Shashank Sharma
Some common questions from automated driving engineers

How can I synthesize scenarios to test my designs?

How can I discover and design in multiple domains?

How can I integrate with other environments?

Perception

Planning

Control

Simulation Integration

ROS

CAN

C/C++

Python

Cross Release

Third Party

MATLAB EXPO 2019
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SIMULATION INTEGRATION

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MATLAB EXPO 2019
Graphically author driving scenarios

**Driving Scenario Designer**
- Create roads and lane markings
- Add actors and trajectories
- Specify actor size and radar cross-section (RCS)
- Explore pre-built scenarios
- Import OpenDRIVE roads

**Automated Driving Toolbox™**

R2018a
Integrate driving scenarios into Simulink simulations

Test Open-Loop ADAS Algorithm Using Driving Scenario
- Edit driving scenario
- Integrate into Simulink
- Add sensor models
- Visualize results
- Pace simulation

Automated Driving Toolbox™
Simulate driving scenarios into closed loop simulations

**Automatic Emergency Braking (AEB) with Sensor Fusion**
- Specify driving scenario
- Design AEB logic
- Integrate sensor fusion
- Simulate system
- Generate C/C++ code
- Test with software in the loop (SIL) simulation

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

MATLAB EXPO 2019
Automate testing against driving scenarios

**Testing a Lane Following Controller with Simulink Test**
- Specify driving scenario

*Simulink Test™
Automated Driving Toolbox™
Model Predictive Control Toolbox™
R2018b
MATLAB EXPO 2019
Synthesize driving scenarios from recorded data

Scenario Generation from Recorded Vehicle Data
- Visualize video
- Import OpenDRIVE roads
- Import GPS
- Import object lists

Automated Driving Toolbox™

MATLAB EXPO 2019
How can I design with virtual scenarios?

<table>
<thead>
<tr>
<th>Scenes</th>
<th>Driving Scenarios (cuboid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing</td>
<td>Controls</td>
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<tr>
<td></td>
<td>Controls + sensor fusion</td>
</tr>
<tr>
<td>Authoring</td>
<td>Driving Scenario Designer App</td>
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<tr>
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<td>drivingScenario programmatic API</td>
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<tr>
<td>Sensing</td>
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How can I design with virtual scenarios?

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<th>Unreal Engine</th>
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<td>Probabilistic radar detections Probabilistic vision detections Probabilistic lane detections</td>
<td>Ideal camera (viewer)</td>
</tr>
</tbody>
</table>
Simulate controls and perception systems

Lane Following Control with Sensor Fusion
- Model Predictive Control Toolbox™
- Automated Driving Toolbox™
- Embedded Coder®

Visual Perception Using Monocular Camera
- Automated Driving Toolbox™

Lane-Following Control with Monocular Camera Perception
- Model Predictive Control Toolbox™
- Automated Driving Toolbox™
- Vehicle Dynamics Blockset™

MathWorks Expo 2019
Simulate lane controls with vision based perception

**Lane-Following Control with Monocular Camera Perception**

- Integrate Simulink controller
  - Lane follower
  - Spacing control
- Integrate MATLAB perception
  - Lane boundary detector
  - Vehicle detector
- Synthesize ideal camera image from Unreal Engine

*Model Predictive Control Toolbox™*
*Automated Driving Toolbox™*
*Vehicle Dynamics Blockset™*
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MATLAB EXPO 2019
Design trackers

From various sensors at various update rates

- Multi-object tracker
- Linear, extended, and unscented Kalman filters

Multi-Object Tracker

Association & Track Management

Tracking Filter

Detections

Tracks
Design trackers

Multi-Object Tracker

Association & Track Management

Tracking Filter

Tracks

Detections

From various sensors at various update rates

- Multi-object tracker
- Global Nearest Neighbor (GNN) tracker
- Joint Probabilistic Data Association (JPDA) tracker
- Track-Oriented Multi-Hypothesis Tracker (TOMHT)
- Probability Hypothesis Density (PHD) tracker

- Linear, extended, and unscented Kalman filters
- Particle, Gaussian-sum, IMM filters

Automated Driving Toolbox™
Sensor Fusion and Tracking Toolbox™
MATLAB EXPO 2019
Design multi-object trackers

Extended Object Tracking
- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking metrics
- Evaluate error metrics
- Evaluate desktop execution time

Sensor Fusion and Tracking Toolbox™
Automated Driving Toolbox™
Updated R2019a
Design extended object trackers

**Extended Object Tracking**
- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking metrics
- Evaluate error metrics
- Evaluate desktop execution time

**Sensor Fusion and Tracking Toolbox™**

**Automated Driving Toolbox™**

Updated R2019a
Evaluate tracking performance

Extended Object Tracking
- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking metrics
- Evaluate error metrics
- Evaluate desktop execution time

Sensor Fusion and Tracking Toolbox™
Automated Driving Toolbox™
Updated R2019a

Multi-object tracker
Probability Hypothesis Density tracker
Extended object (size and orientation) tracker
Evaluate error metrics

**Extended Object Tracking**
- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking metrics
- Evaluate error metrics
- Evaluate desktop execution time

**Sensor Fusion and Tracking Toolbox™**

**Automated Driving Toolbox™**

Updated R2019a

![Error Metrics Graphs]

- Multi-object tracker
- Probability Hypothesis Density tracker
- Extended object (size and orientation) tracker
Compare relative execution times of object trackers

**Extended Object Tracking**
- Design multi-object tracker
- Design extended object trackers
- Evaluate tracking performance
- Evaluate error metrics
- Evaluate desktop execution time

**Sensor Fusion and Tracking Toolbox™**
**Automated Driving Toolbox™**

Updated R2019a
Design detector for lidar point cloud data

Track Vehicles Using Lidar: From Point Cloud to Track List

- Design 3-D bounding box detector
- Design tracker (target state and measurement models)
- Generate C/C++ code for detector and tracker

Sensor Fusion and Tracking Toolbox™

Computer Vision Toolbox™

R2019a
Generate C/C++ code for lidar detector and tracker

Track Vehicles Using Lidar: From Point Cloud to Track List
- Design 3-D bounding box detector
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Sensor Fusion and Tracking Toolbox™
Computer Vision Toolbox™
Create region of interest labels and groups

Get Started with the Ground Truth Labeler
- Label rectangles
- Label lane markings
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

Automated Driving Toolbox™

Updated R2019a
Add custom visualizations for multi-sensor data

Connect Lidar Display to Ground Truth Labeler
- Sync external tool to each frame change
- Control external tool through playback controls

Automated Driving Toolbox™

R2017a
Interoperate with neural network frameworks

Open Neural Network Exchange
Design camera, lidar, and radar perception algorithms

- Detect vehicle with camera
- Detect ground with lidar
- Detect pedestrian with radar

Object Detection Using YOLO v2 Deep Learning
Computer Vision Toolbox™
Deep Learning Toolbox™

Segment Ground Points from Organized Lidar Data
Computer Vision Toolbox™

Introduction to Micro-Doppler Effects
Phased Array System Toolbox™

R2019a
MATLAB EXPO 2019

R2018b

R2019a
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MATLAB EXPO 2019
Visualize HERE HD Live Map recorded data

Use HERE HD Live Map Data to Verify Lane Configurations
- Load camera and GPS data
- Retrieve speed limit
- Retrieve lane configurations
- Visualize composite data

Automated Driving Toolbox™

MATLAB EXPO 2019
Design path planner

Automated Parking Valet
- Create cost map of environment
- Inflate cost map for collision checking
- Specify goal poses
- Plan path using rapidly exploring random tree (RRT*)

Automated Driving Toolbox™

MATLAB EXPO 2019
Design path planner and controller

Automated Parking Valet with Simulink

- Integrate path planner
- Design lateral controller (based on vehicle kinematics)
- Design longitudinal controller (PID)
- Simulate closed loop with vehicle dynamics

Automated Driving Toolbox™

MATLAB EXPO 2019
Generate C/C++ code for path planner and controller

Code Generation for Path Planning and Vehicle Control
- Simulate system
- Configure for code generation
- Generate C/C++ code
- Test using Software-In-the-Loop
- Measure execution time of generated code

Automated Driving Toolbox™
Embedded Coder

R2019a
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MATLAB EXPO 2019
Design lateral and longitudinal Model Predictive Controllers

**Longitudinal Control**

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

**Lateral Control**

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

**Longitudinal + Lateral**

Lane Following Control with Sensor Fusion and Lane Detection
Automated Driving Toolbox™
Model Predictive Control Toolbox™
Embedded Coder®
Reinforcement Learning?

- What is Reinforcement Learning?
  - Type of machine learning that trains an ‘agent’ through repeated interactions with an environment

- How does it work?
  - Through a trial & error process that uses a reward system to maximize success
Train reinforcement learning networks for ADAS controllers

Train Deep Deterministic Policy Gradient (DDPG) Agent for Adaptive Cruise Control

- Create environment interface
- Create agent
- Train agent
- Simulate trained agent

Reinforcement Learning Toolbox™

R2019a
Some common questions from automated driving engineers

- How can I synthesize scenarios to test my designs?
- How can I discover and design in new domains?
- How can I integrate with other environments?

Control → Planning → Perception

Simulation Integration:
- ROS
- CAN
- C/C++
- Python
- Cross Release
- Third Party

MATLAB EXPO 2019
Integrate with ROS

Replay logged ROS data

Connect to live ROS data

Generate standalone ROS node

Work with rosbag Logfiles
Robotic System Toolbox™

Exchange Data with ROS Publishers and Subscribers
Robotic System Toolbox™

Generate a Standalone ROS Node from Simulink
Robotic System Toolbox™
SimulinkCoder™
Call C++, Python, and OpenCV from MATLAB

Call C++

- Import C++ Library Functionality into MATLAB

Call Python

- Call Python from MATLAB

Install and Use Computer Vision Toolbox OpenCV Interface

Call OpenCV & OpenCV GPU

- Call OpenCV & OpenCV GPU

R2019a

R2014a

Updated R2018b
Call C code from Simulink

Call C code

Create buses from C structs

Test and verify C code

Bring Custom Image Filter Algorithms as Reusable Blocks in Simulink

Import Structure and Enumerated Types

Custom C Code Verification with Simulink Test

MATLAB EXPO 2019
Connect to third party tools

152 Interfaces to 3rd Party Modeling and Simulation Tools
(as of March 2019)
Cross-release simulation through code generation

Integrate Generated Code by Using Cross-Release Workflow

- Generate code from previous release (R2010a or later)
- Import generated code as a block in current release
- Tune parameters
- Access internal signals

Embedded Coder

R2016a

Previous Release

Current Release
Some common questions from automated driving engineers

Synthesize scenarios to test my designs
Discover and design in multiple domains
Integrate with other environments

Perception
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MATLAB EXPO 2019
MathWorks can help you customize MATLAB and Simulink for your automated driving application

Voyage develops MPC controller and integrates with ROS
- 2018 MathWorks Automotive Conference

Autoliv labels ground truth lidar data
- Joint presentation with Autoliv
- SAE Paper 2018-01-0043
- 2018 MathWorks Automotive Conference

Ford tests algorithms with synthetic Lidar data from Unreal Engine
- Joint paper with Ford
- SAE Paper 2017-01-0107
Develop Automated Driving Systems with MATLAB and Simulink

Discuss your application with a MathWorks field engineer to help you structure your evaluation

- Understand your goals
- Recommend tasks
- Answer questions