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?

Simulation Integration

Perception

Planning

Control

ROS

CAN

C/C++

Python

Cross Release

Third Party

MATLAB EXPO 2019
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?
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™

MATLAB EXPO 2019
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™

R2019a
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>
</tr>
<tr>
<td></td>
<td>Controls + sensor fusion</td>
</tr>
<tr>
<td>Authoring</td>
<td>Driving Scenario Designer App</td>
</tr>
<tr>
<td></td>
<td>drivingScenario programmatic API</td>
</tr>
<tr>
<td>Sensing</td>
<td>Probabilistic radar detections</td>
</tr>
<tr>
<td></td>
<td>Probabilistic vision detections</td>
</tr>
<tr>
<td></td>
<td>Probabilistic lane detections</td>
</tr>
</tbody>
</table>
### How can I design with virtual scenarios?

<table>
<thead>
<tr>
<th>Scenes</th>
<th>Driving Scenarios (cuboid)</th>
<th>Unreal Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image" alt="Scenes Diagram" /></td>
<td><img src="image" alt="Unreal Engine Image" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Testing</th>
<th>Controls</th>
<th>Controls + sensor fusion</th>
<th>Controls</th>
<th>Controls + vision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authoring</td>
<td>Driving Scenario Designer App</td>
<td>drivingScenario programmatic API</td>
<td>Unreal Editor</td>
<td></td>
</tr>
</tbody>
</table>

| Sensing | Probabilistic radar detections | Probabilistic vision detections | Probabilistic lane detections | Ideal camera (viewer) |
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™

R2018b
APR 2019

R2017a

R2018b
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™*
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
Design trackers

Multi-Object Tracker

Association & Track Management

Tracking Filter

Tracks

Detections

From various sensors at various update rates

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

Automated Driving Toolbox™
Design trackers

Multi-Object Tracker

Association & Track Management

Tracking Filter

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

MATLAB EXPO 2019
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

MATLAB EXPO 2019
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
- Design tracker (target state and measurement models)
- Generate C/C++ code for detector and tracker

Sensor Fusion and Tracking Toolbox™
Computer Vision Toolbox™ R2019a
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™
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?

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™

R2019a
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™ R2018b*
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**
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?

Control

Perception

Planning

Simulation Integration

ROS

CAN

C/C++

Python

Cross Release

Third Party

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™

MATLAB EXPO 2019
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?
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++

Call Python

Call OpenCV & OpenCV GPU

Import C++ Library Functionality into MATLAB MATLAB®

R2019a

Call Python from MATLAB MATLAB®

R2014a

Install and Use Computer Vision Toolbox OpenCV Interface

Computer Vision System Toolbox™

OpenCV Interface Support Package

Updated R2018b

R2014a
Call C code from Simulink

Call C code

Create buses from C structs

typedef struct {
    double coeff;
    double init;
    fault T fault;
} params T;

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
Simulink Test™
Simulink Coverage™

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
Some common questions from automated driving engineers

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

Perception
Planning
Control

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

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
  MATLAB EXPO 2019

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