MATLAB EXPO 2019

Diseño y Simulación de Sistemas de Conducción Autónoma con MATLAB y Simulink

Lucas García
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?
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

**MathWorks**
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™ R2019a
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™

Requirements link
Simulink Model
Define scenario ID and data initialization
Plot the results
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>
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<th>Controls</th>
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How can I design with virtual scenarios?

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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™*
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

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How can I integrate with other environments?
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
Create sublabels and add attributes

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
Create polyline labels and add attributes

**Get Started with the Ground Truth Labeler**
- Label rectangles
- Label lane markings
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**Automated Driving Toolbox™**

Updated R2019a
Create pixel labels

**Get Started with the Ground Truth Labeler**
- Label rectangles
- Label lane markings
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- Label scenes
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- Add label attributes

**Automated Driving Toolbox™**

*Updated R2019a*
Create scene 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
Import custom automation algorithms

**Automate Attributes of Labeled Objects**
- Import automation algorithm into Ground Truth Labeling app
- Detect vehicles from monocular camera
- Estimate distance to detected vehicles
- Run automation algorithm and interactively validate labels

*Automated Driving Toolbox™ R2018b*
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*
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™
Design trackers

Multi-Object Tracker

Association & Track Management

Tracking Filter

Tracks

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™
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
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- 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
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- Evaluate desktop execution time

**Sensor Fusion and Tracking Toolbox™**

**Automated Driving Toolbox™**

Updated R2019a
Evaluate error metrics

**Extended Object Tracking**
- Design multi-object tracker
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**Sensor Fusion and Tracking Toolbox™**

**Automated Driving Toolbox™**

*Updated R2019a*
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
Some common questions from automated driving engineers

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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™

R2018α
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

MATLAB EXPO 2019
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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®
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

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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™ Simulink Coder™
Call C++, Python, and OpenCV from MATLAB

**Call C++**

- Import C++ Library Functionality into MATLAB
  - MATLAB®
  - R2019a

**Call Python**

- Call Python from MATLAB
  - MATLAB®
  - R2014a

**Call OpenCV & OpenCV GPU**

- Install and Use Computer Vision Toolbox OpenCV Interface
  - Computer Vision System Toolbox™
  - OpenCV Interface Support Package

- 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

Simulink Test™

Simulink Coverage™
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
Connect to third party tools

152 Interfaces to 3rd Party Modeling and Simulation Tools
(as of March 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
Some common questions from automated driving engineers

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

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

Control
Planning
Perception