MATLAB EXPO 2019

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

Lucas García
Some common questions from automated driving engineers

1. **How can I synthesize scenarios to test my designs?**
2. **How can I discover and design in multiple domains?**
3. **How can I integrate with other environments?**

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

**Control**

**Planning**

**Perception**

**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?

![Diagram showing Perception, Planning, Control, Simulation Integration with ROS, CAN, C/C++, Python, Cross Release, Third Party]
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®**
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™
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><strong>Driving Scenarios (cuboid)</strong></th>
</tr>
</thead>
</table>
| Testing | Controls
| | Controls + sensor fusion |
| Authoring | Driving Scenario Designer App
| | drivingScenario programmatic API |
| Sensing | Probabilistic radar detections
| | Probabilistic vision detections
| | Probabilistic lane detections |
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>Testing</td>
<td>Controls</td>
<td>Controls</td>
</tr>
<tr>
<td></td>
<td>Controls + sensor fusion</td>
<td>Controls + vision</td>
</tr>
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</tr>
<tr>
<td></td>
<td>Probabilistic lane detections</td>
<td></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™*
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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Perception → Planning → Control

Simulation Integration:
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Control
Planning
Perception

MATLAB EXPO 2019
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
- Label pixels
- Label scenes
- Create label groups
- Create sublabels
- Add label attributes

*Automated Driving Toolbox™*

Updated R2019a
Create pixel labels

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 scene labels and groups

Get Started with the Ground Truth Labeler

- Label rectangles
- Label lane markings
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- 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™*
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**
  - Object Detection Using YOLO v2 Deep Learning
    - Computer Vision Toolbox™
    - Deep Learning Toolbox™

- **Detect ground with lidar**
  - Segment Ground Points from Organized Lidar Data
    - Computer Vision Toolbox™

- **Detect pedestrian with radar**
  - Introduction to Micro-Doppler Effects
    - Phased Array System Toolbox™
Design trackers

- 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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**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
Evaluate error metrics

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

**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

How can I synthesize scenarios to test my designs?

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Perception

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Control

Simulation Integration

ROS

CAN

C/C++

Python

Cross Release

Third Party

CAN
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™**
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*
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Python

Cross Release
Third Party

MATLAB EXPO 2019
Design lateral and longitudinal Model Predictive Controllers

Longitudinal Control

Lateral Control

Longitudinal + Lateral

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 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

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

Call C++

- .hpp
- .mlx

Call Python

- py.textwrap.TextWrapper(...
  pyargs(...
    'initial_indent', '% ', ...
    'subsequent_indent', '% ', ...
    'width', int32(30)))

Call OpenCV & OpenCV GPU

- cv::Rect
- cv::KeyPoint
- cv::Size
- cv::Mat
- cv::Ptr

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
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™
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
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- Integrate with other environments

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Cross Release Third Party

MathWorks
MATLAB EXPO 2019