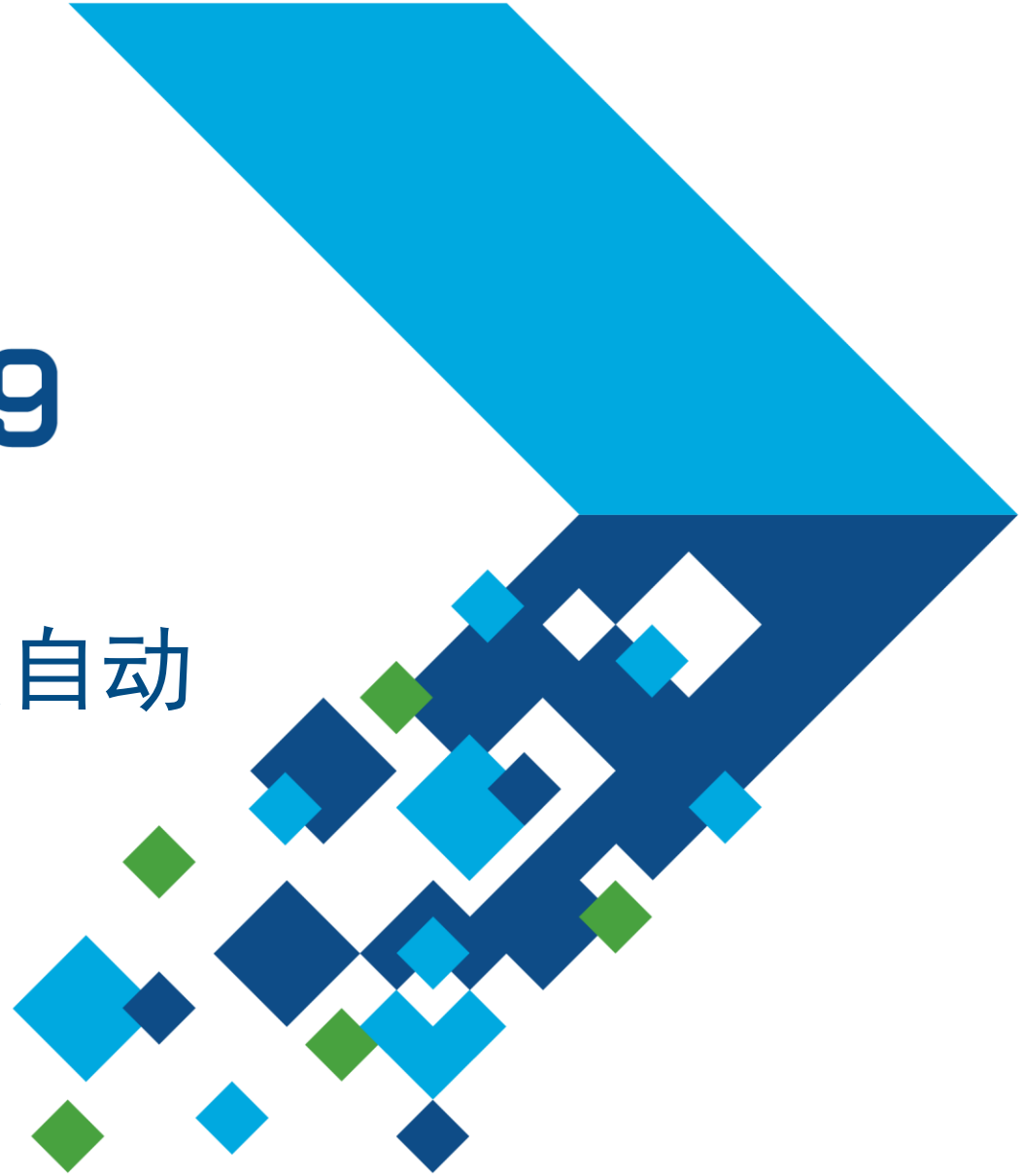
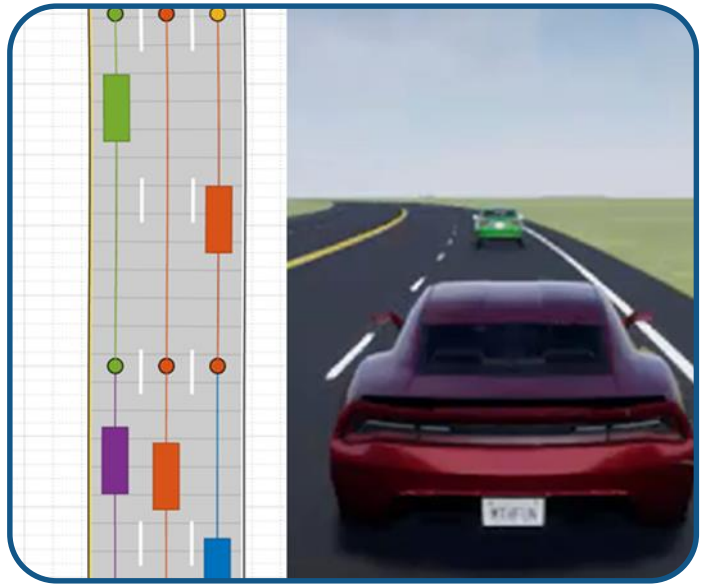
MATLAB EXPO 2019

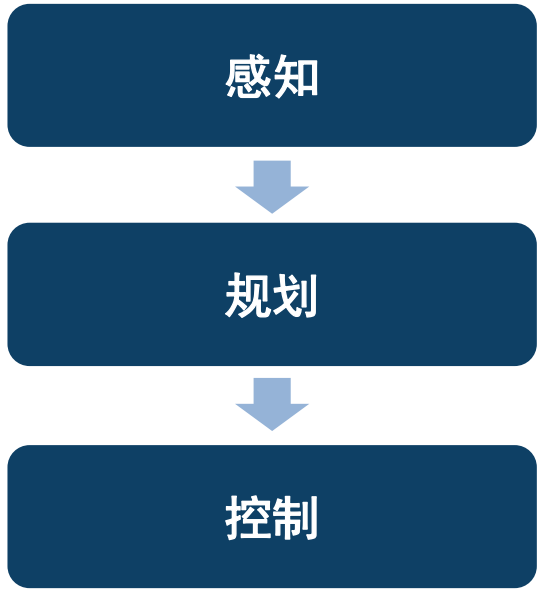
MATLAB和Simulink用于开发自动驾驶的新特性

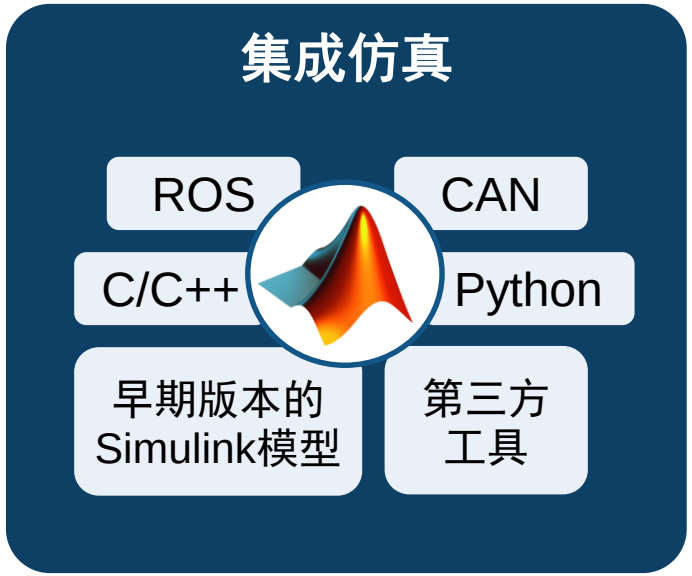
王鸿钧，MathWorks 中国



自动驾驶工程师的几个常见问题







如何创建虚拟驾驶场景来测试我的设计？

如何串联和加速多个专业的算法开发？

如何将其他资源集成到我们的仿真环境？

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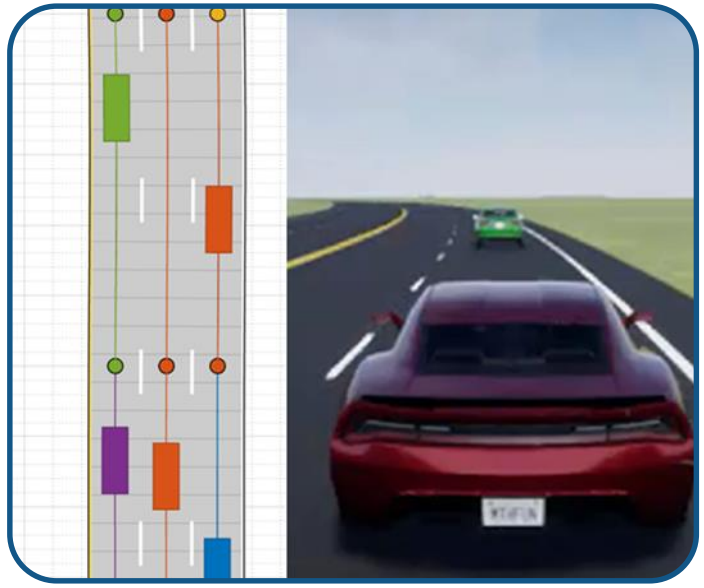

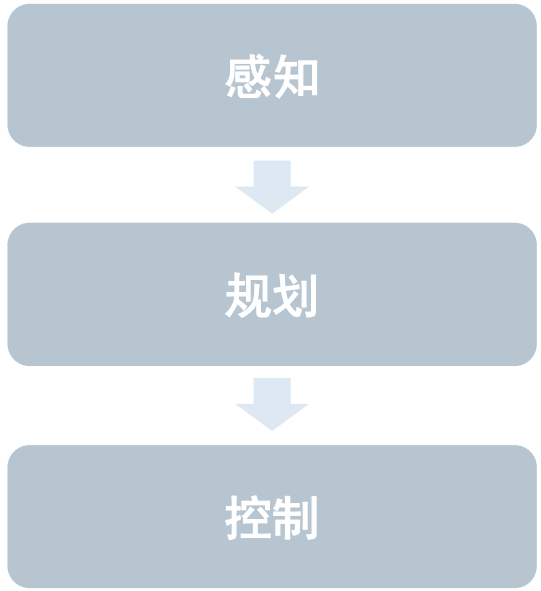

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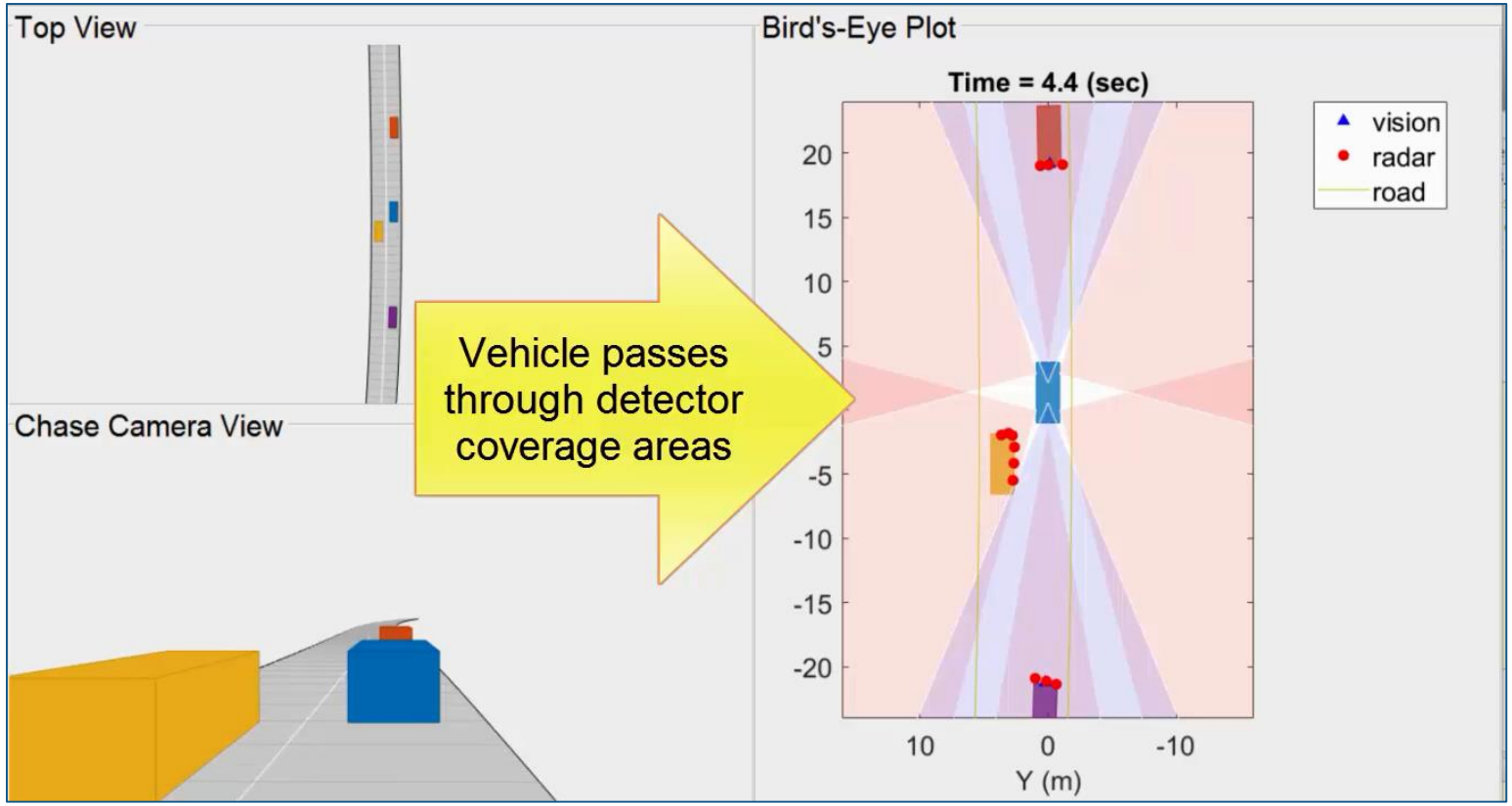
创建虚拟驾驶场景

[Sensor Fusion Using Synthetic Radar and Vision Data]

- 模拟道路和车辆
- 添加基于统计概率的视觉与雷达传感器
- 测试传感器融合与目标跟踪
- 可视化传感器覆盖区域, 检测列表, 目标跟踪列表

Automated Driving Toolbox™

R2017a



图形化的驾驶场景设计器

[Driving Scenario Designer]

- 创建道路与车道线标记
- 添加车辆与行驶轨迹
- 设置车辆尺寸与雷达截面积(RCS)
- 提供预定义的ADAS场景
- 支持导入OpenDRIVE格式路网文件

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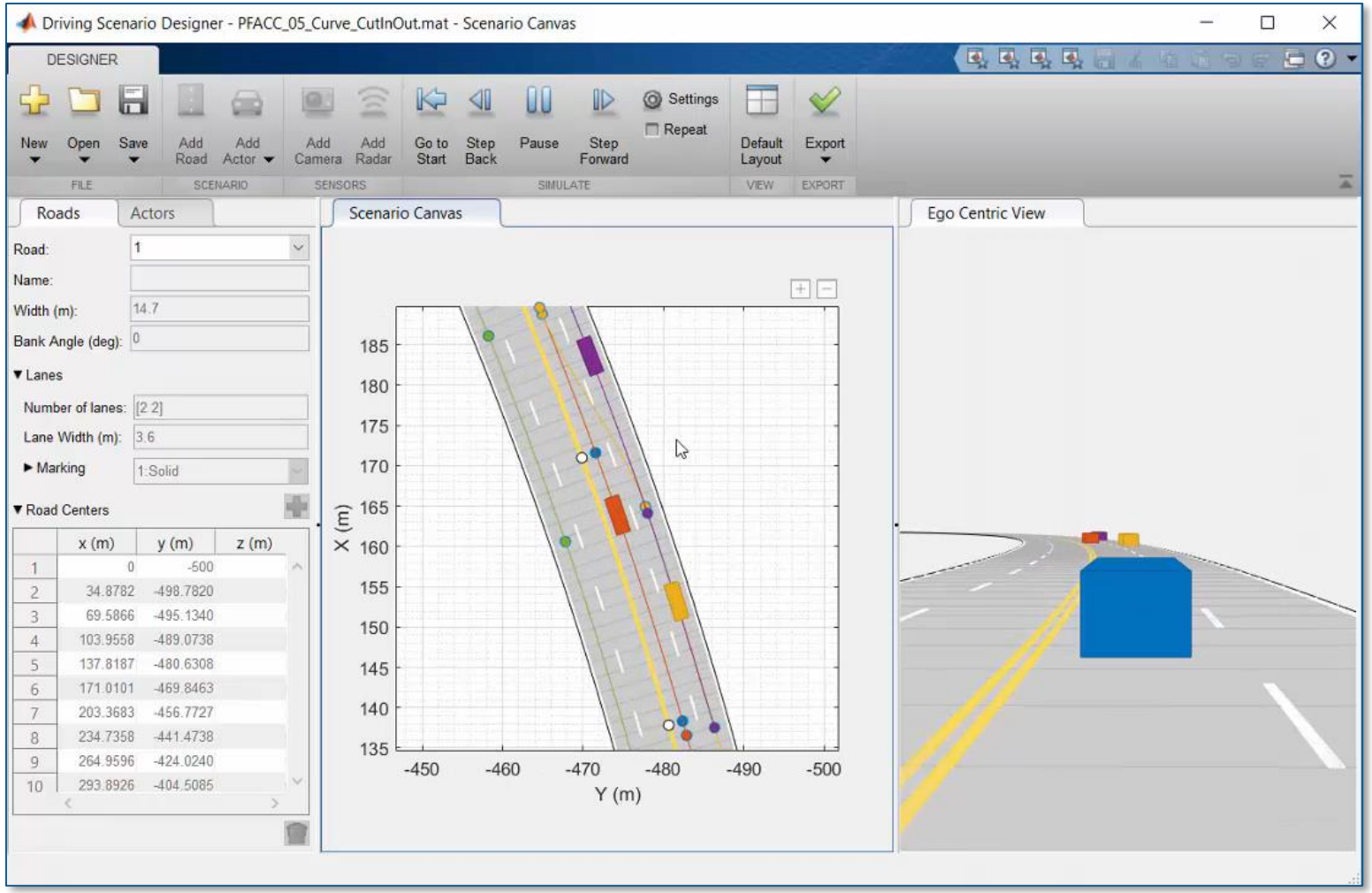
R2018a



在Simulink中仿真驾驶场景

[Test Open-Loop ADAS Algorithm Using Driving Scenario]

- 编辑驾驶场景
- 在Simulink中读取场景
- 添加传感器模型
- 可视化传感器输出
- 调节仿真速度

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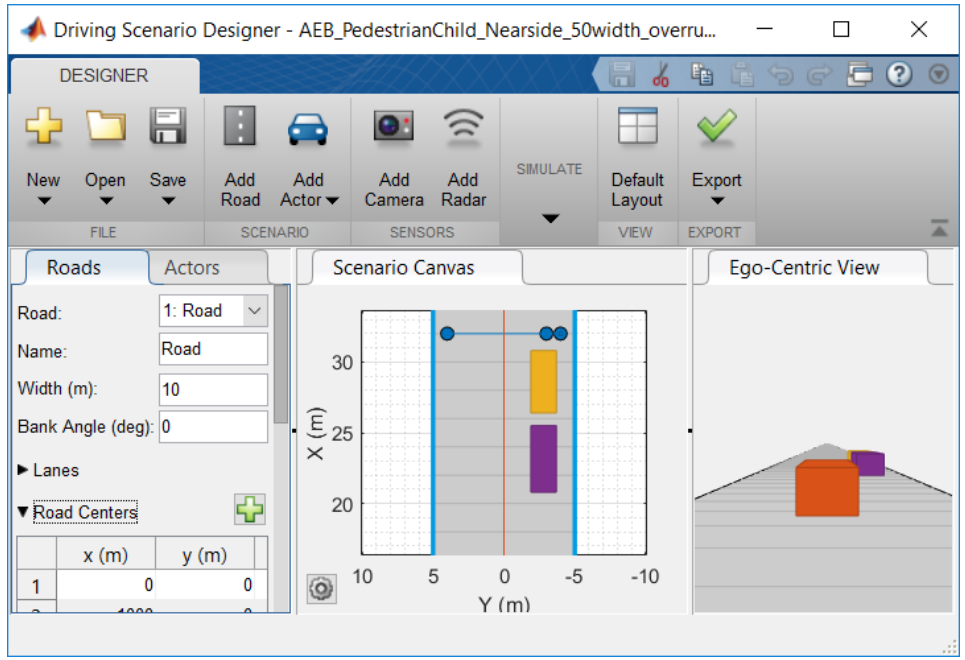
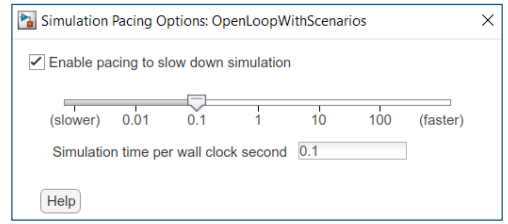
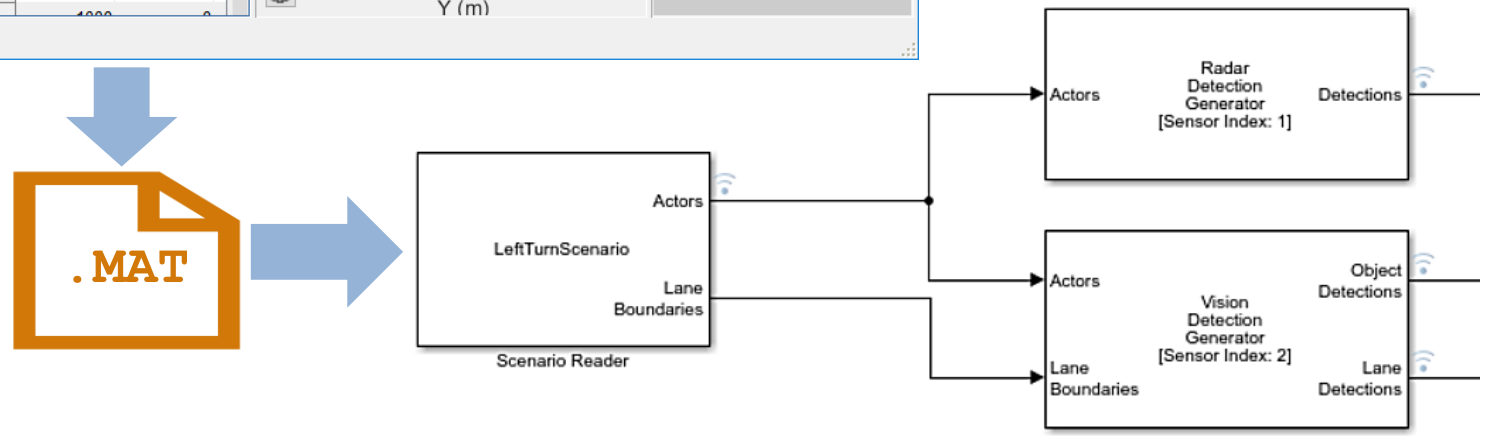


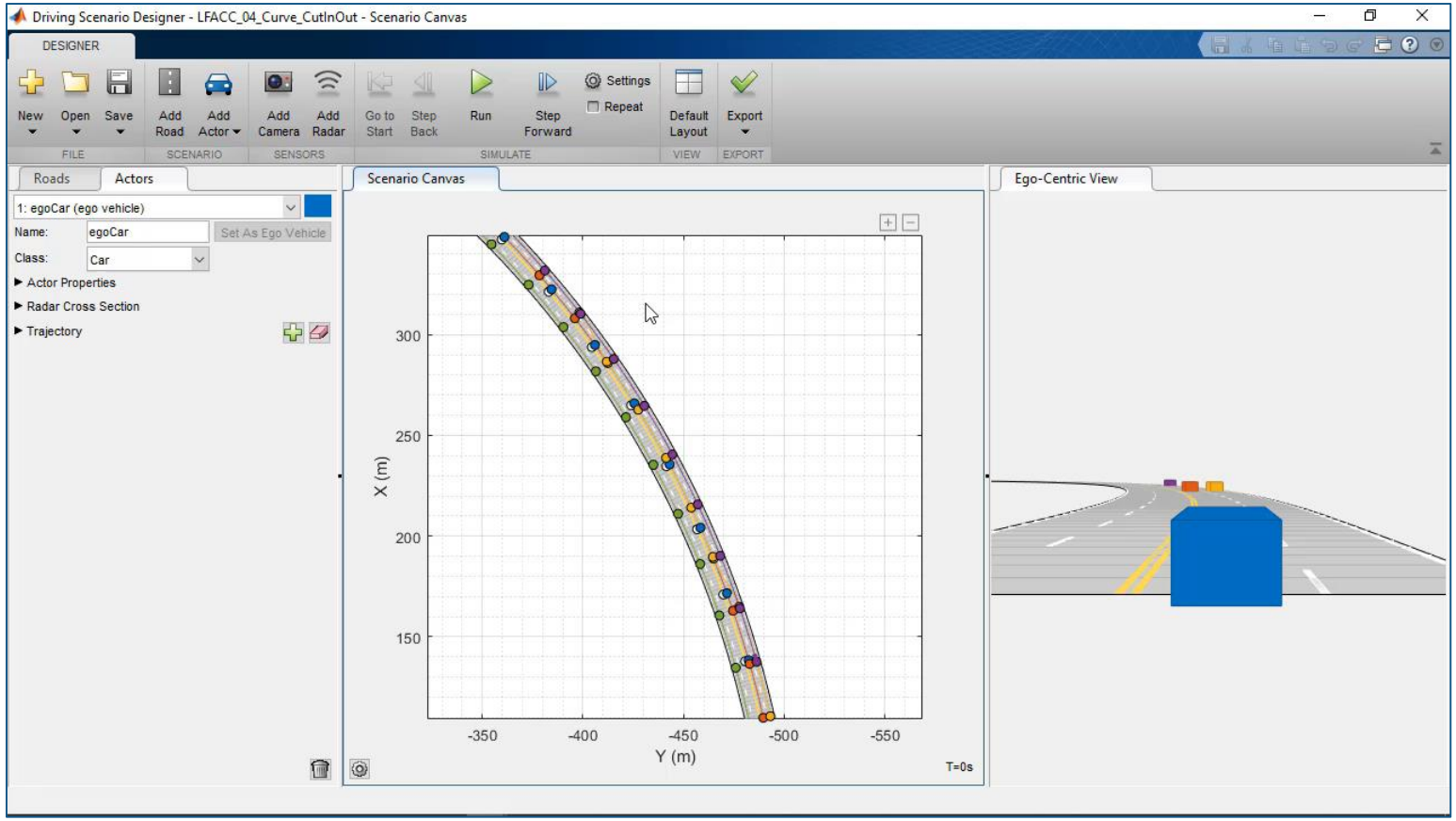




在Simulink中仿真驾驶场景

[Lane Following Control with Sensor Fusion]

- 将场景集成到Simulink
- 设计横向（车道保持）与纵向（间距管理）模型预测控制器
- 设计传感器融合
- 生成C/C++代码
- 软件在环 (SIL) 测试



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设计车辆的横向与纵向控制

[Lane Following Control with Sensor Fusion]

- 将场景集成到Simulink
- 设计横向（车道保持）与纵向（间距管理）模型预测控制器
- 设计传感器融合
- 生成C/C++代码
- 软件在环 (SIL) 测试

Model Predictive Control Toolbox™
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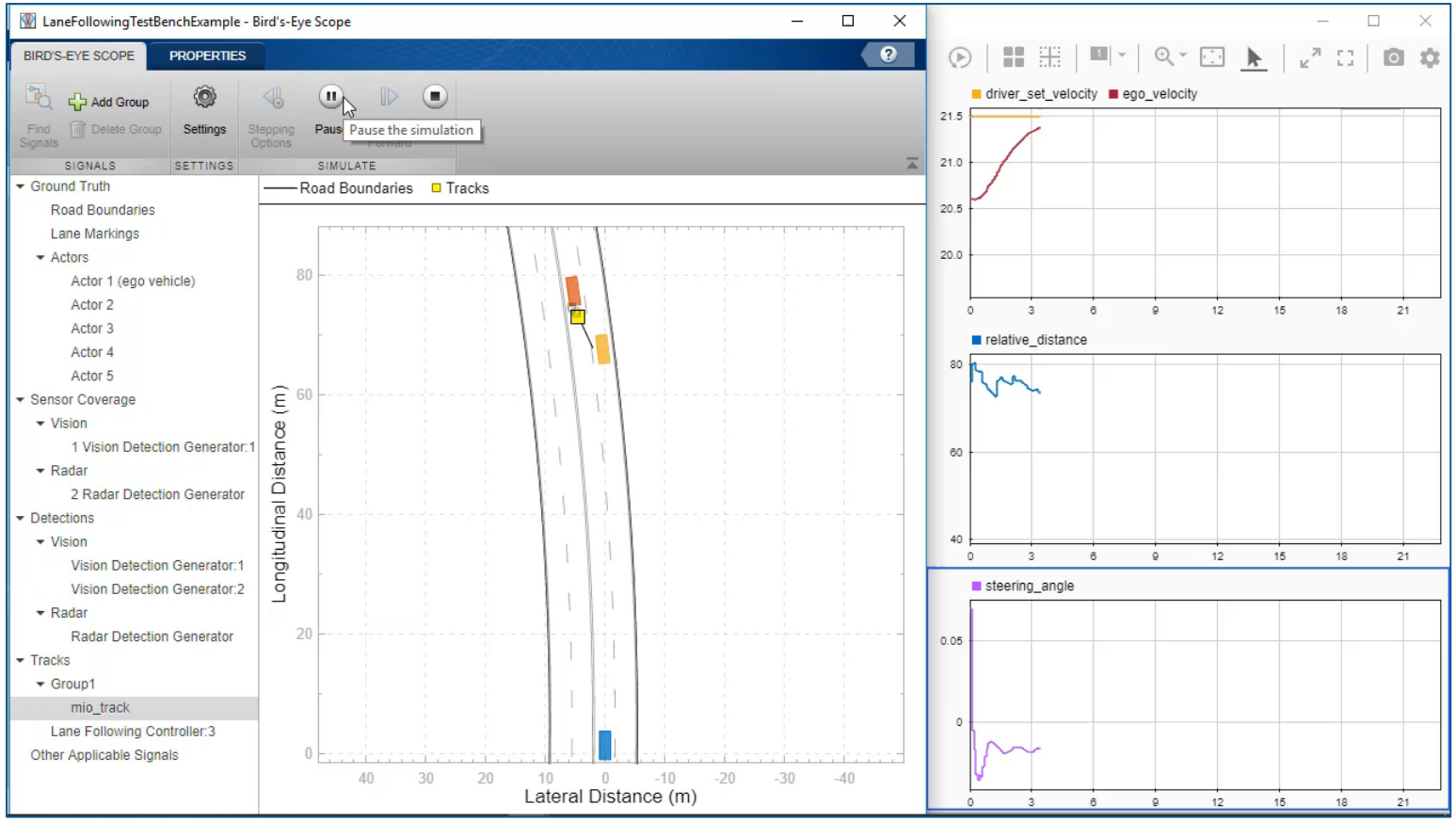

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可视化传感器检测列表与目标跟踪列表

[Lane Following Control with Sensor Fusion]

- 将场景集成到Simulink
- 设计横向（车道保持）与纵向（间距管理）模型预测控制器
- 设计传感器融合
- 生成C/C++代码
- 软件在环 (SIL) 测试

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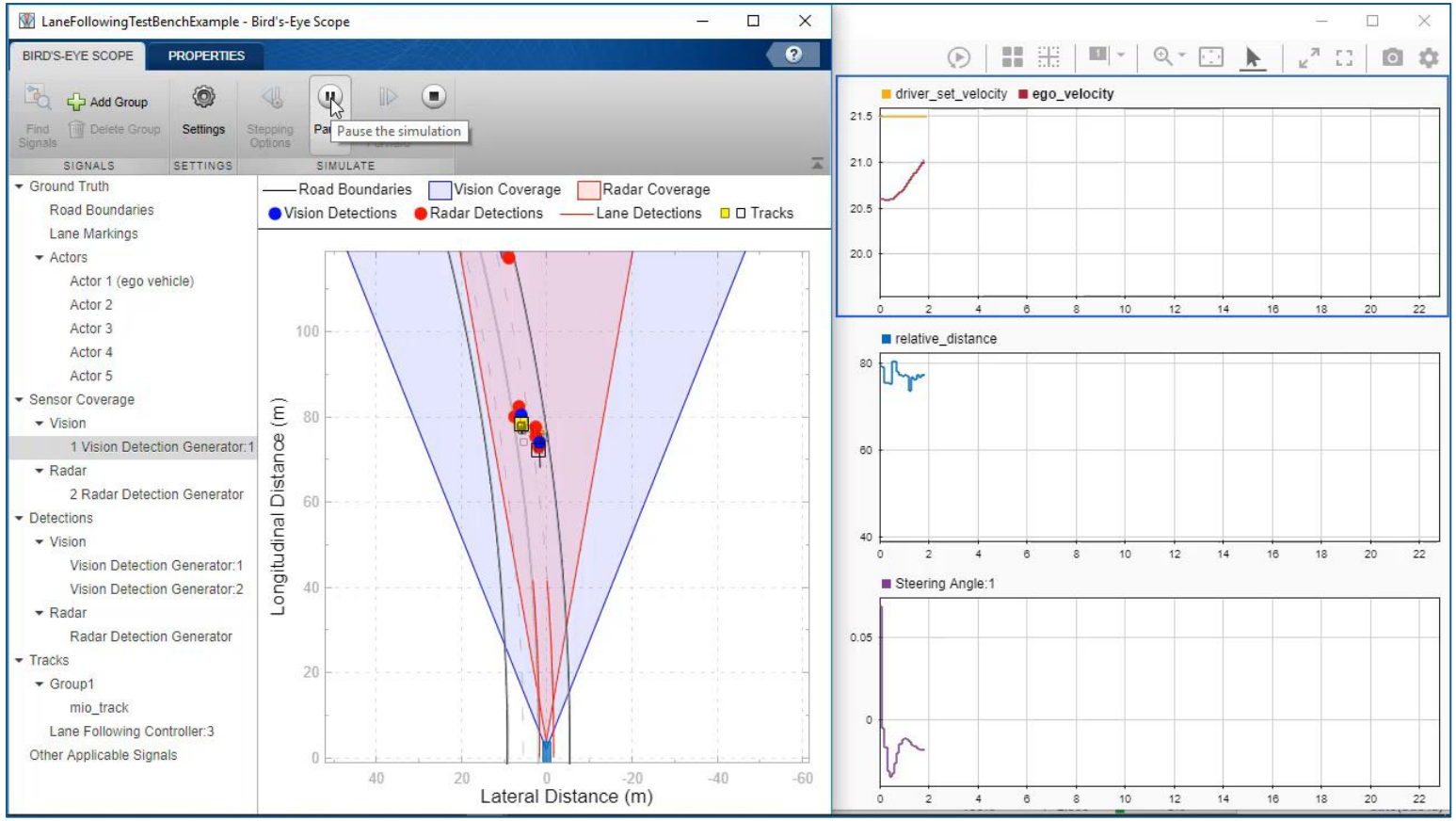

R2018b

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控制算法的自动化测试

[Testing a Lane Following Controller with Simulink Test]

- 指定测试需求与被测模型
- 指定测试通过判据
- 测试结果绘图与报告生成
- 自动化整个测试过程

Simulink Test™

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Model Predictive Control Toolbox™

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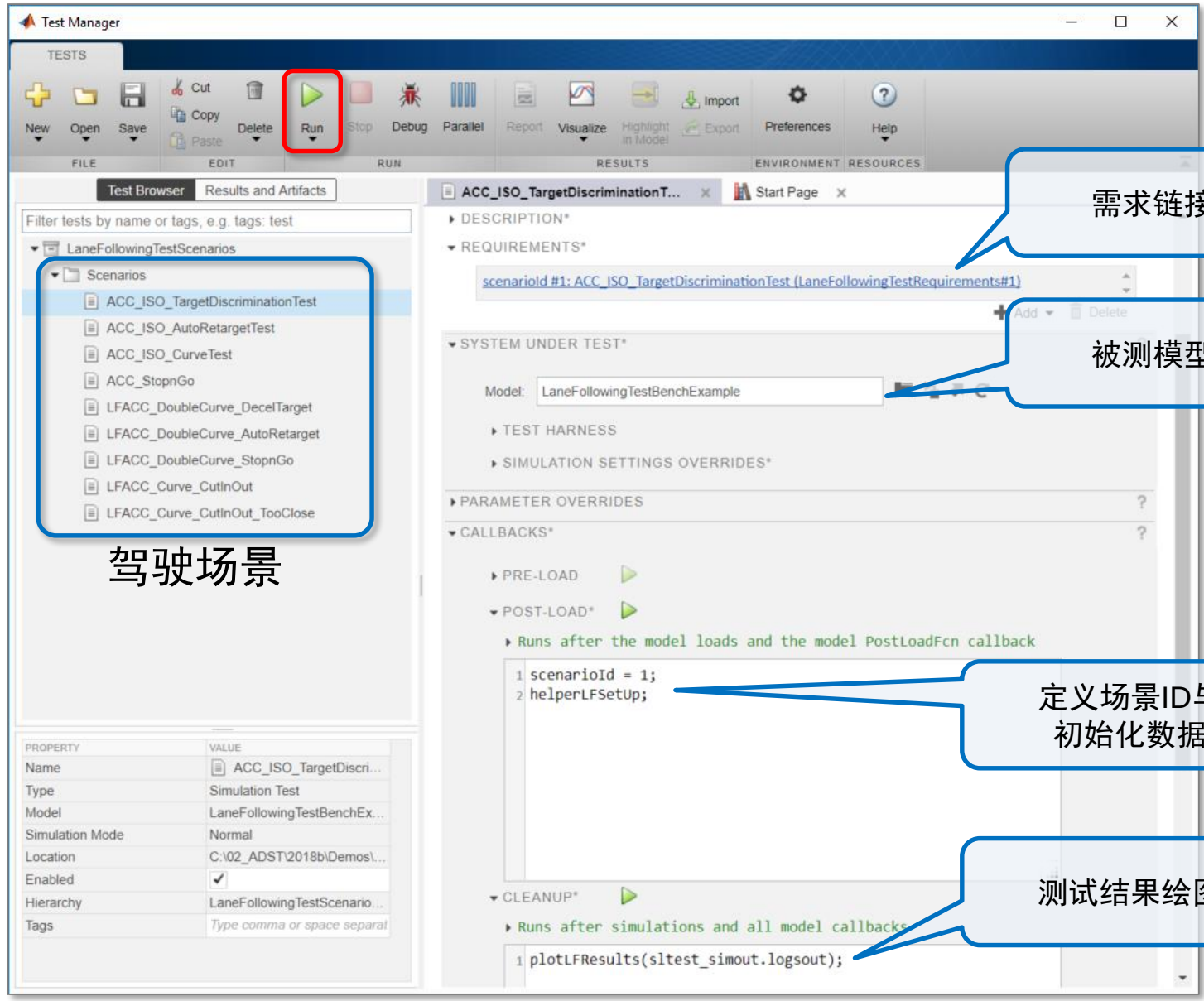

从录制的实车数据生成驾驶场景

[Scenario Generation from Recorded Vehicle Data]

- 回放录制的视频
- 导入OpenDRIVE路网
- 导入GPS数据（本车位置）
- 导入传感器目标列表（其他车辆位置）

Automated Driving Toolbox™

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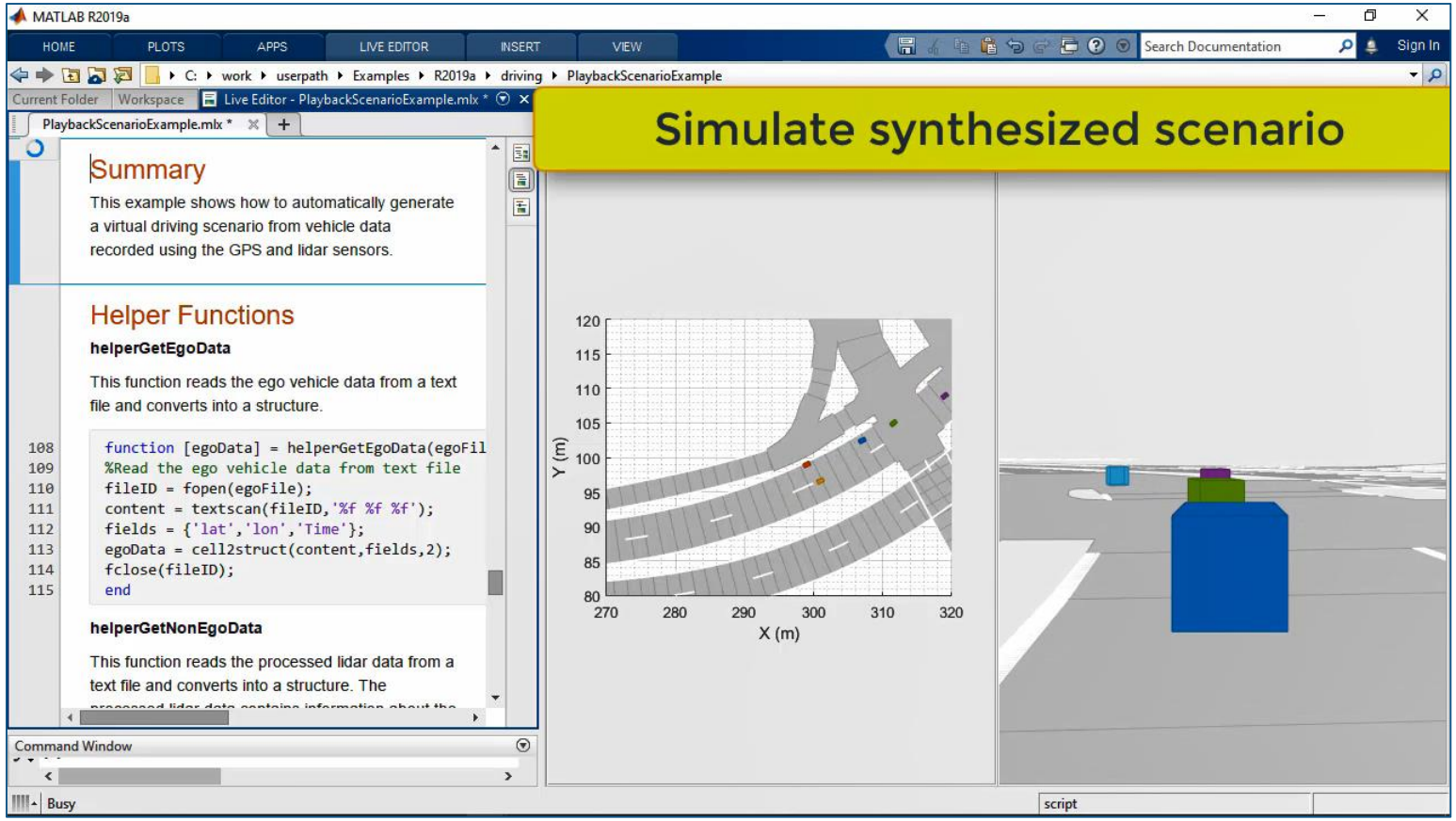
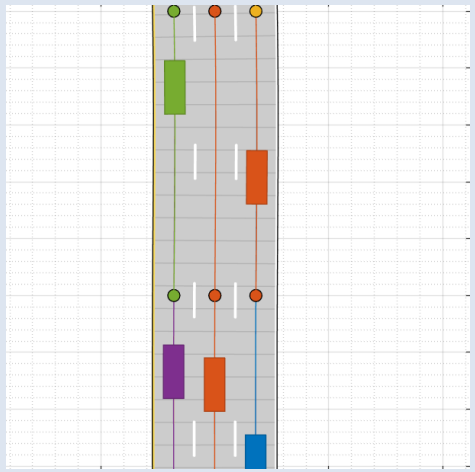
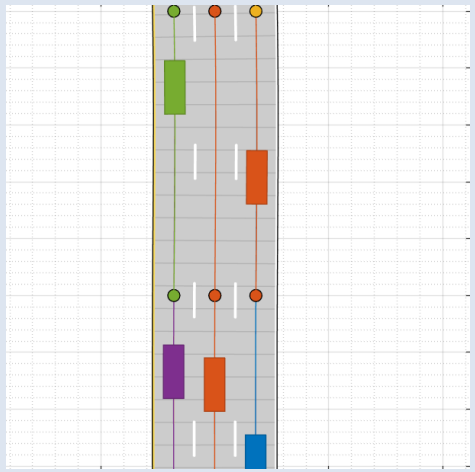


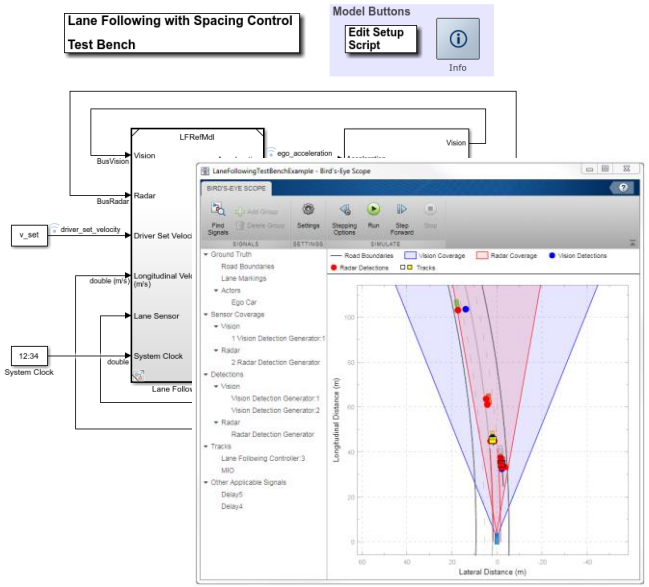
虚拟驾驶场景的两种表达方式

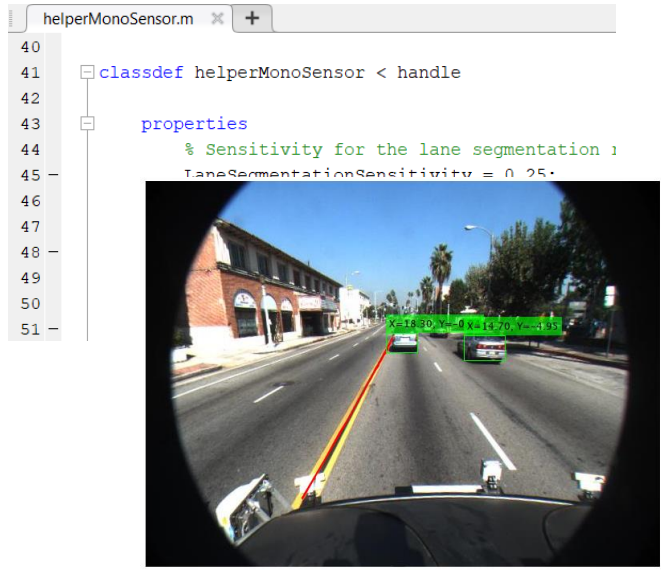
场景表达	**“方块式”驾驶场景** 
可测试算法	控制 控制 + 传感器融合
编辑器	MATLAB提供的驾驶场景设计器及编程接口
传感器模型	基于概率的雷达目标列表 基于概率的视觉目标列表 基于概率的车道线检测列表

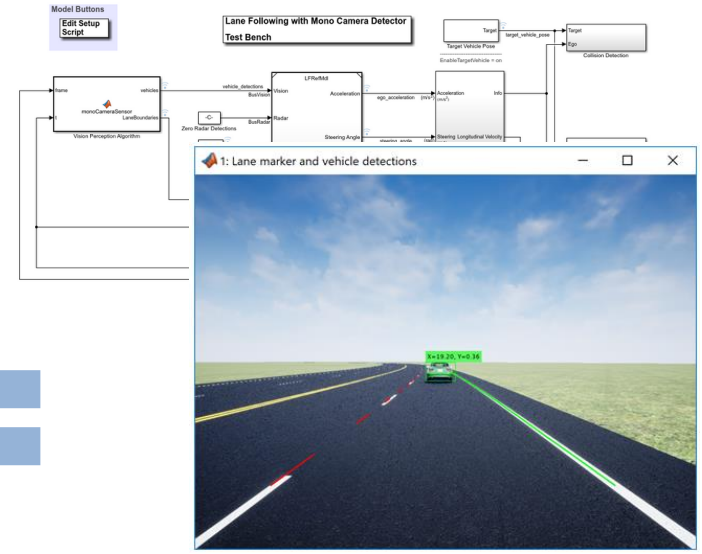
虚拟驾驶场景的两种表达方式

场景表达	“方块式”驾驶场景 	“虚幻”引擎（Unreal Engine） 
可测试算法	控制 控制 + 传感器融合	控制 控制 + 视觉
编辑器	MATLAB提供的驾驶场景设计器及编程接口	“虚幻”编辑器（Unreal Editor）
传感器模型	基于概率的雷达目标列表 基于概率的视觉目标列表 基于概率的车道线检测列表	理想图像传感器

控制与感知系统的集成仿真







[Lane Following Control with Sensor Fusion]

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[Visual Perception Using Monocular Camera]

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[Lane-Following Control with Monocular Camera Perception]

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Vehicle Dynamics Blockset™

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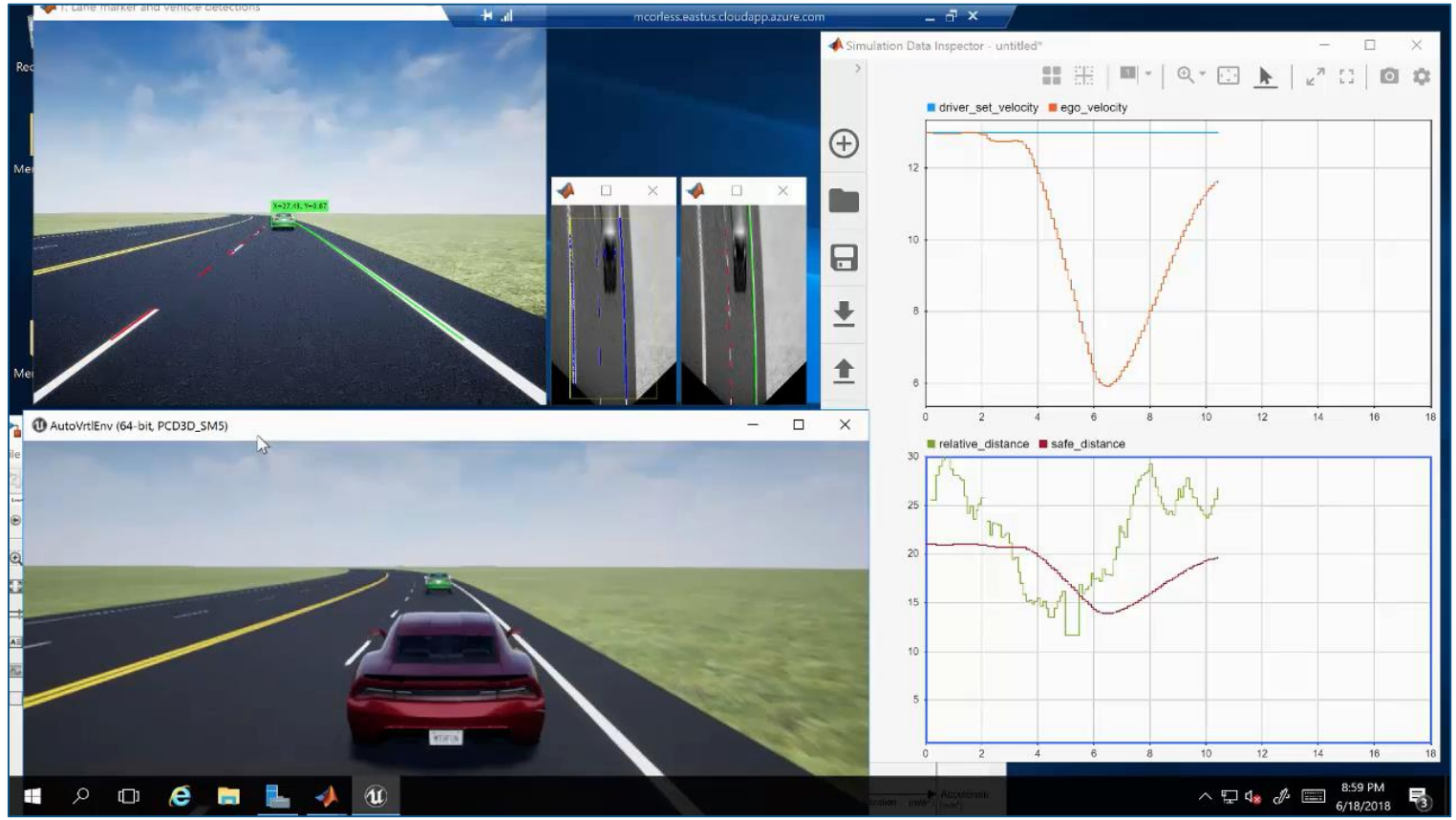
车道跟随控制器与视觉算法的集成仿真

[Lane-Following Control with Monocular Camera Perception]

- 集成Simulink控制器模块
  - 车道跟随
  - 间距控制
- 集成MATLAB图像算法
  - 车道边界检测
  - 车辆检测
- 通过“虚幻”引擎合成理想视觉传感器图像



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Vehicle Dynamics Blockset™

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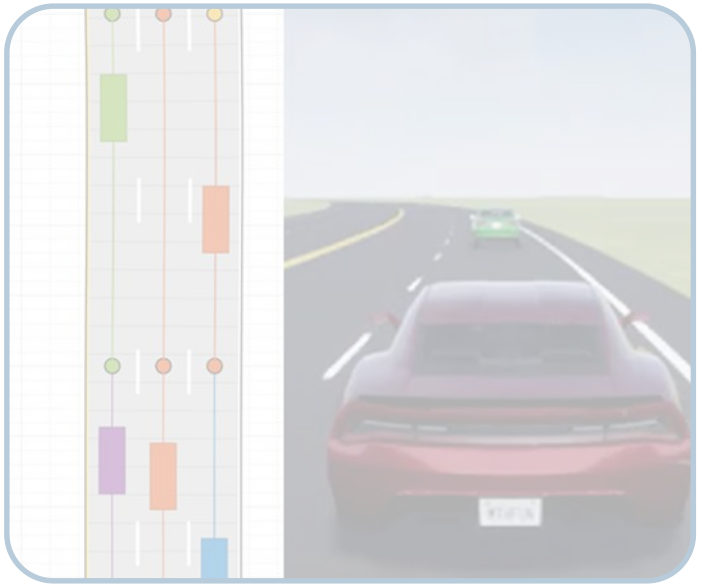

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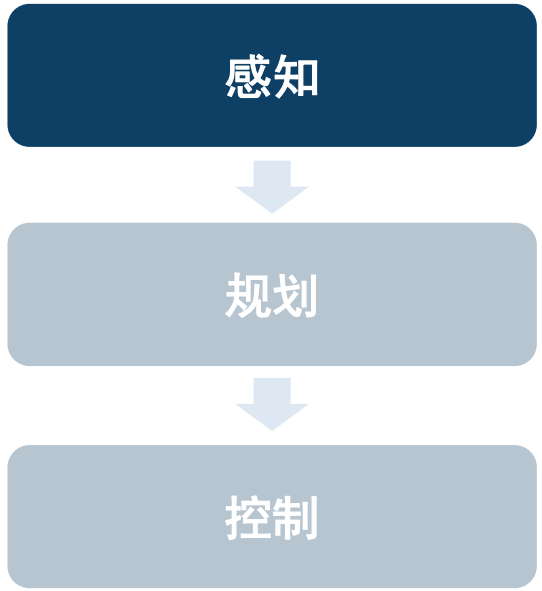

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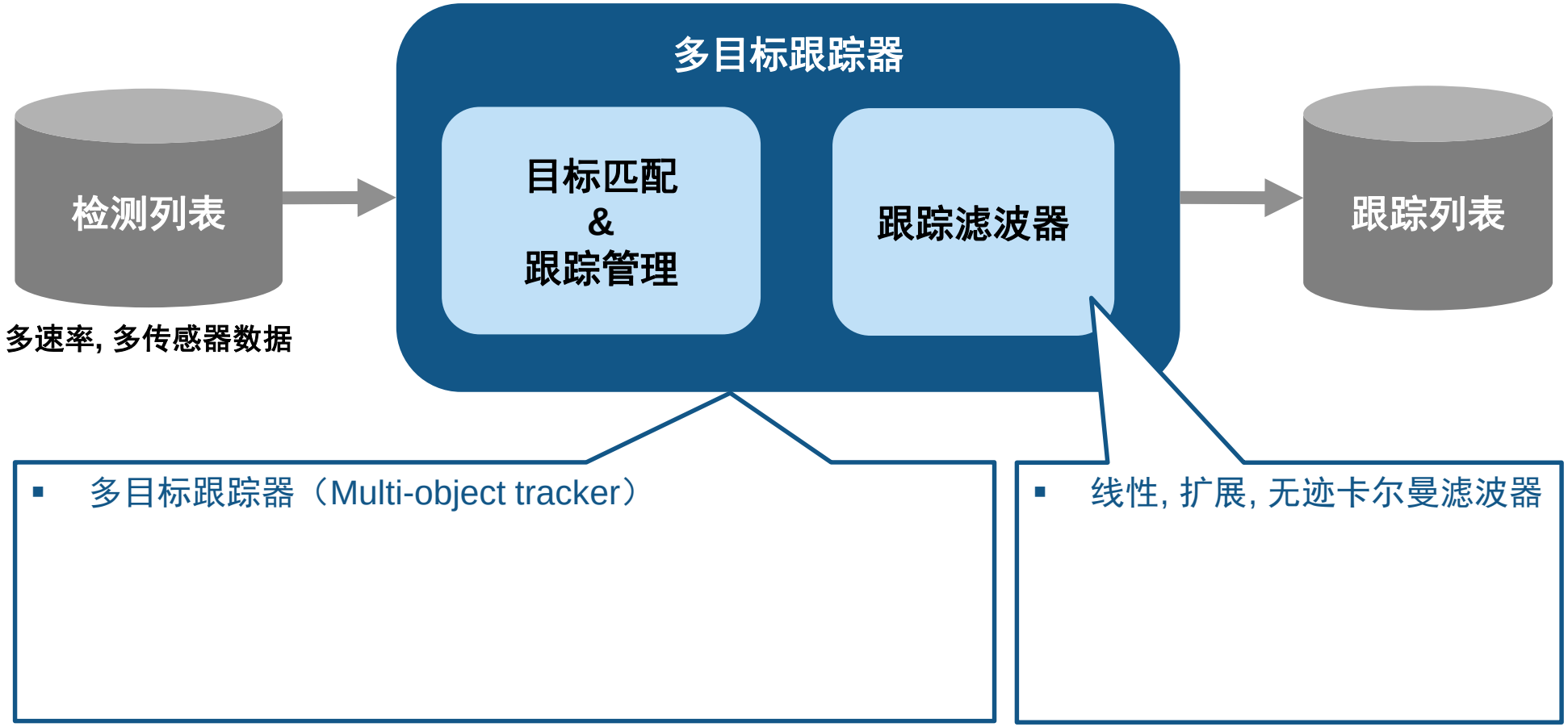
如何将其他资源集成到我们的仿真环境？

传感器融合与目标跟踪



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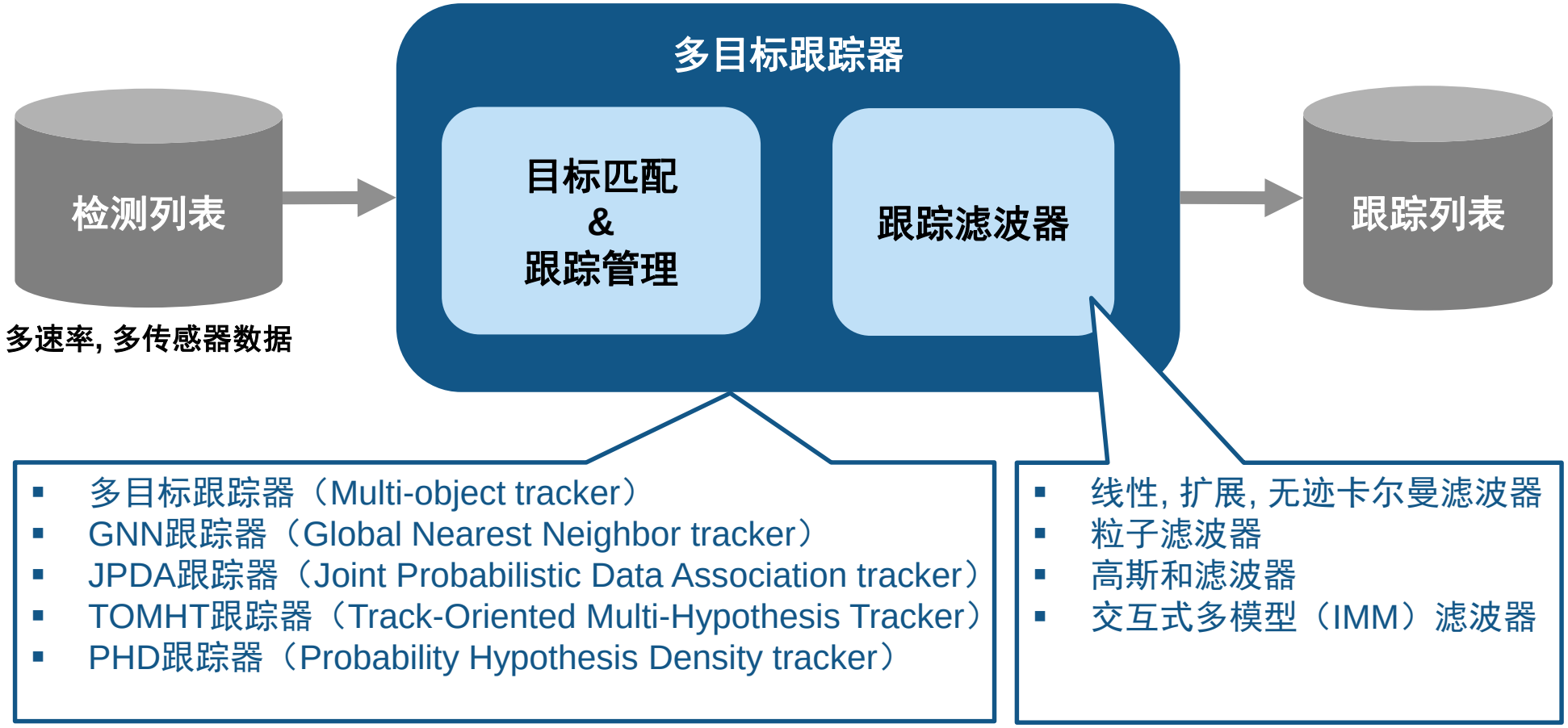
传感器融合与目标跟踪



Automated Driving Toolbox™

Sensor Fusion and Tracking Toolbox™

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点目标跟踪与扩展目标跟踪：点目标跟踪

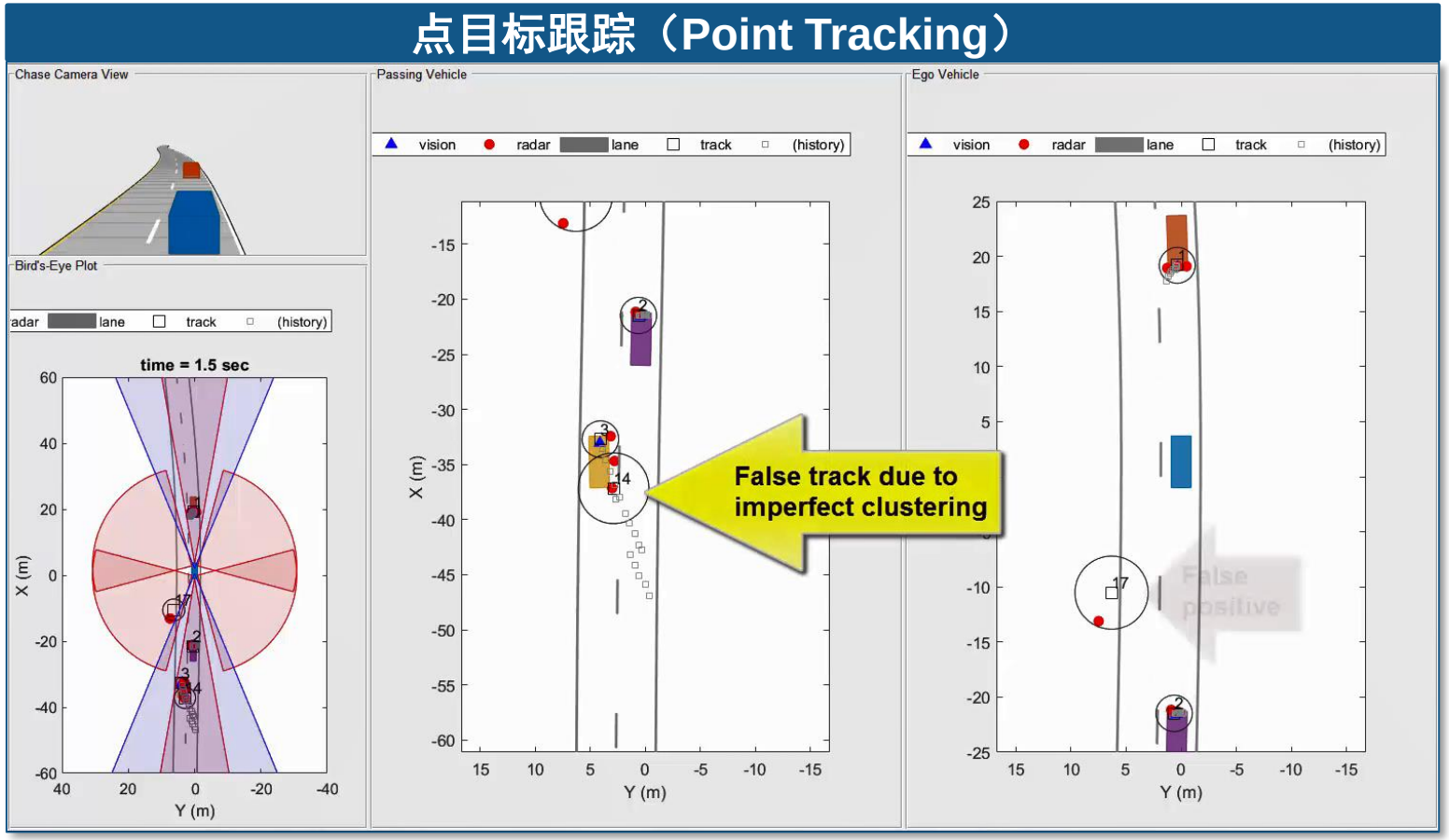
[Extended Object Tracking]

- 点目标跟踪器 multiObjectTracker
- 传感器对单个目标生成单个检测或经过聚类后形成单个检测
- 将目标简化为一个点进行跟踪

Sensor Fusion and Tracking Toolbox™

Automated Driving Toolbox™

Updated R2019a



点目标跟踪与扩展目标跟踪：扩展目标跟踪

[Extended Object Tracking]

- 自定义的扩展目标跟踪器
- 利用高精度传感器对单个目标生成的多个检测
- 可获取更多目标属性：大小、形状、方向等

Sensor Fusion and Tracking Toolbox™

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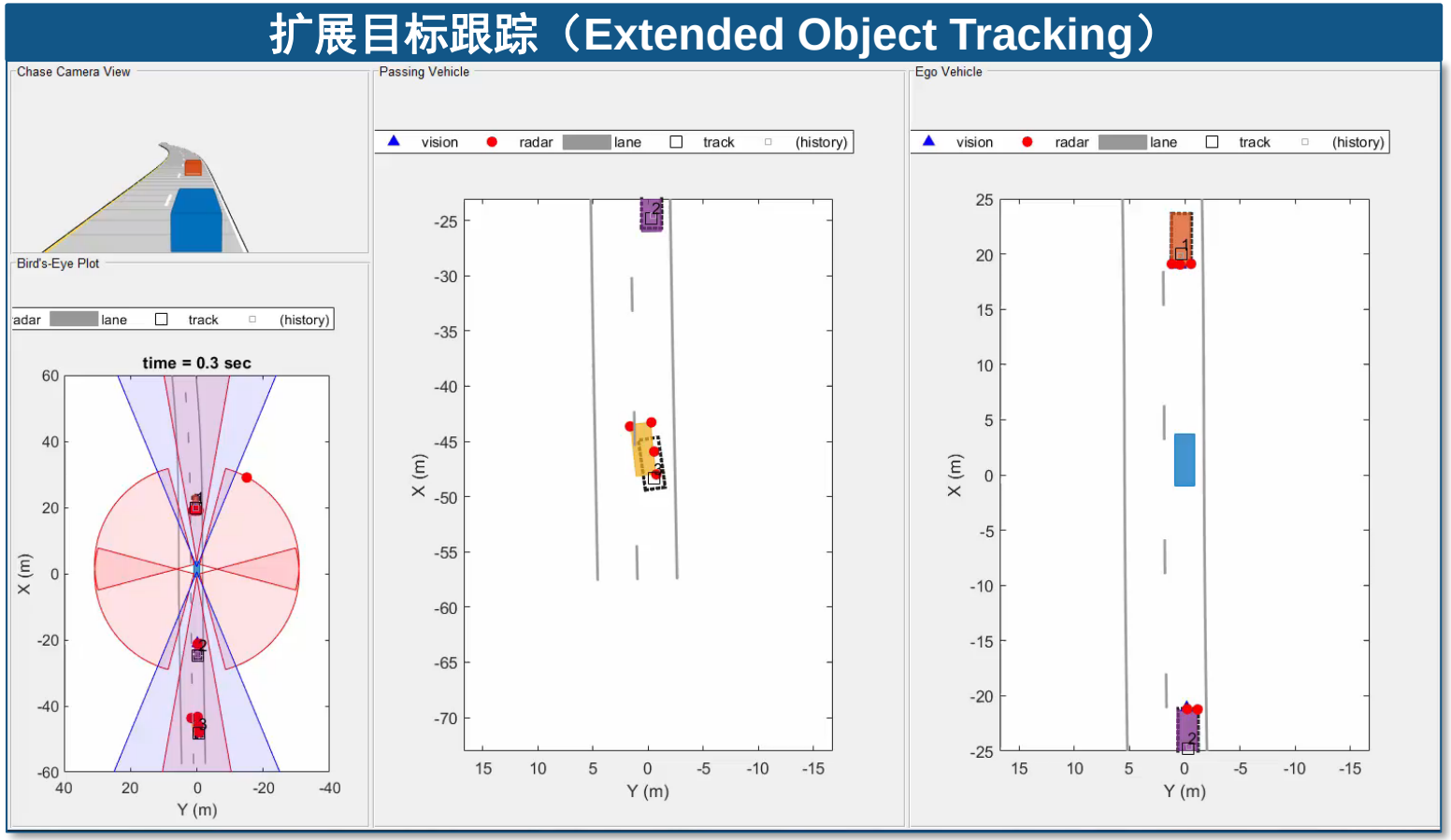
Updated R2019a



点目标跟踪与扩展目标跟踪：评估跟踪性能

Extended Object Tracking

- 评估跟踪性能和误差指标
- 评估算法在桌面的执行时间

Sensor Fusion and Tracking Toolbox™

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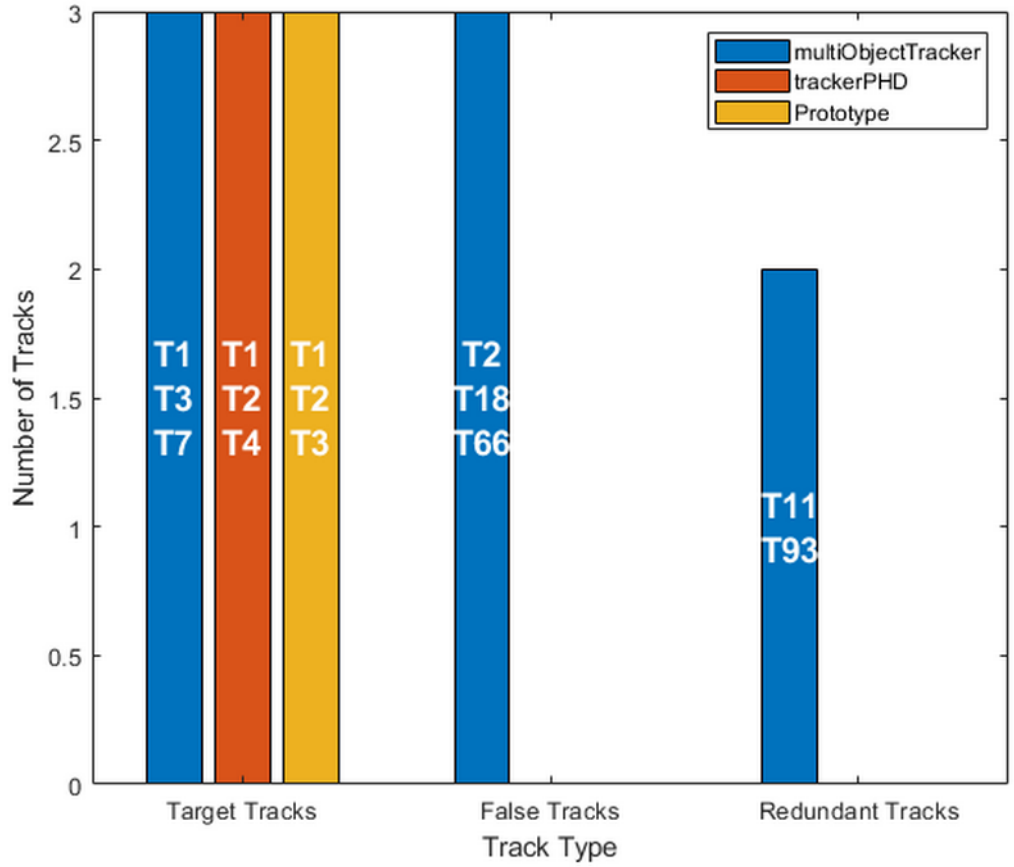
Updated R2019a



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

点目标跟踪与扩展目标跟踪：评估误差指标

[Extended Object Tracking]

- 评估跟踪性能和误差指标
- 评估算法在桌面的执行时间

Sensor Fusion and Tracking Toolbox™

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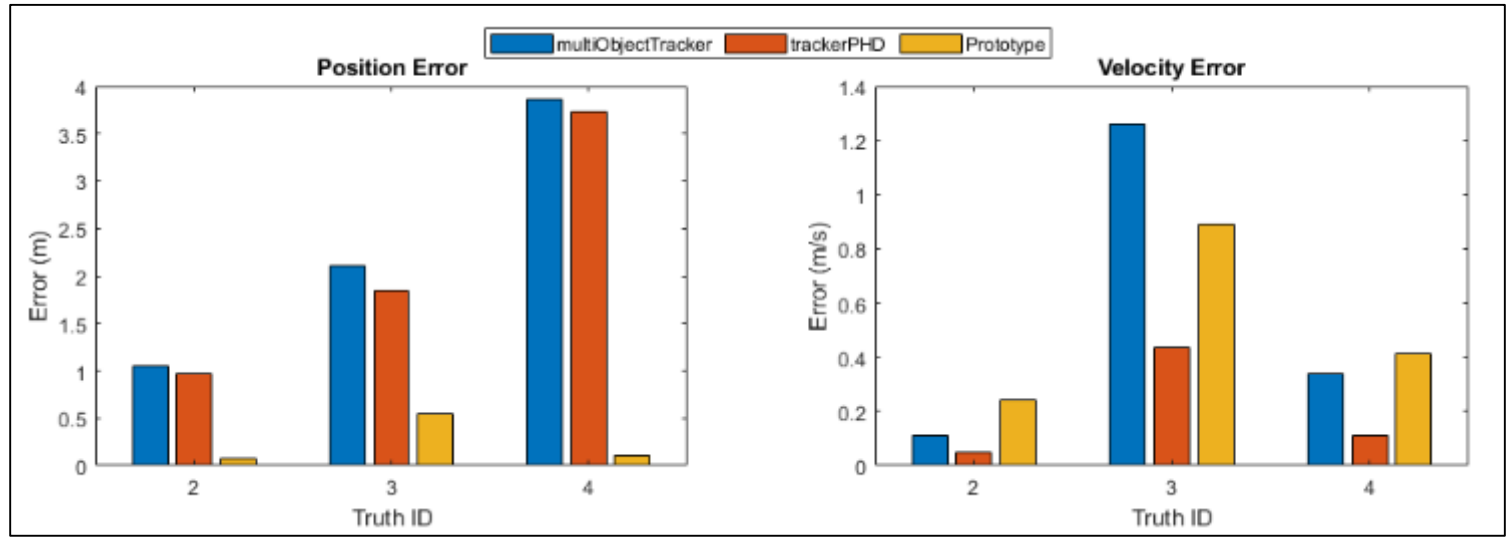

Multi-object tracker
Probability Hypothesis Density tracker
Extended object (size and orientation) tracker

点目标跟踪与扩展目标跟踪：比较算法的相对执行时间

Extended Object Tracking

- 评估跟踪性能和误差指标
- 评估算法在桌面的执行时间

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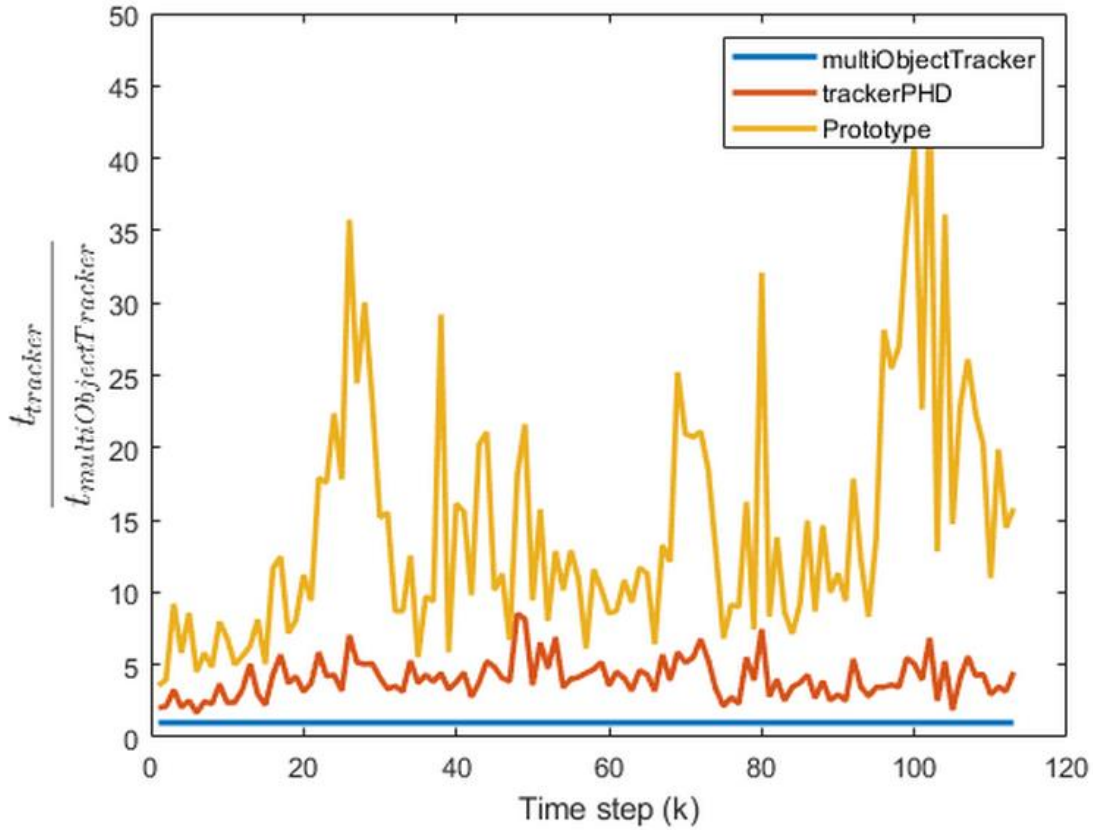


Multi-object tracker
Probability Hypothesis Density tracker
Extended object (size and orientation) tracker

将激光雷达点云转换为目标列表：设计检测器

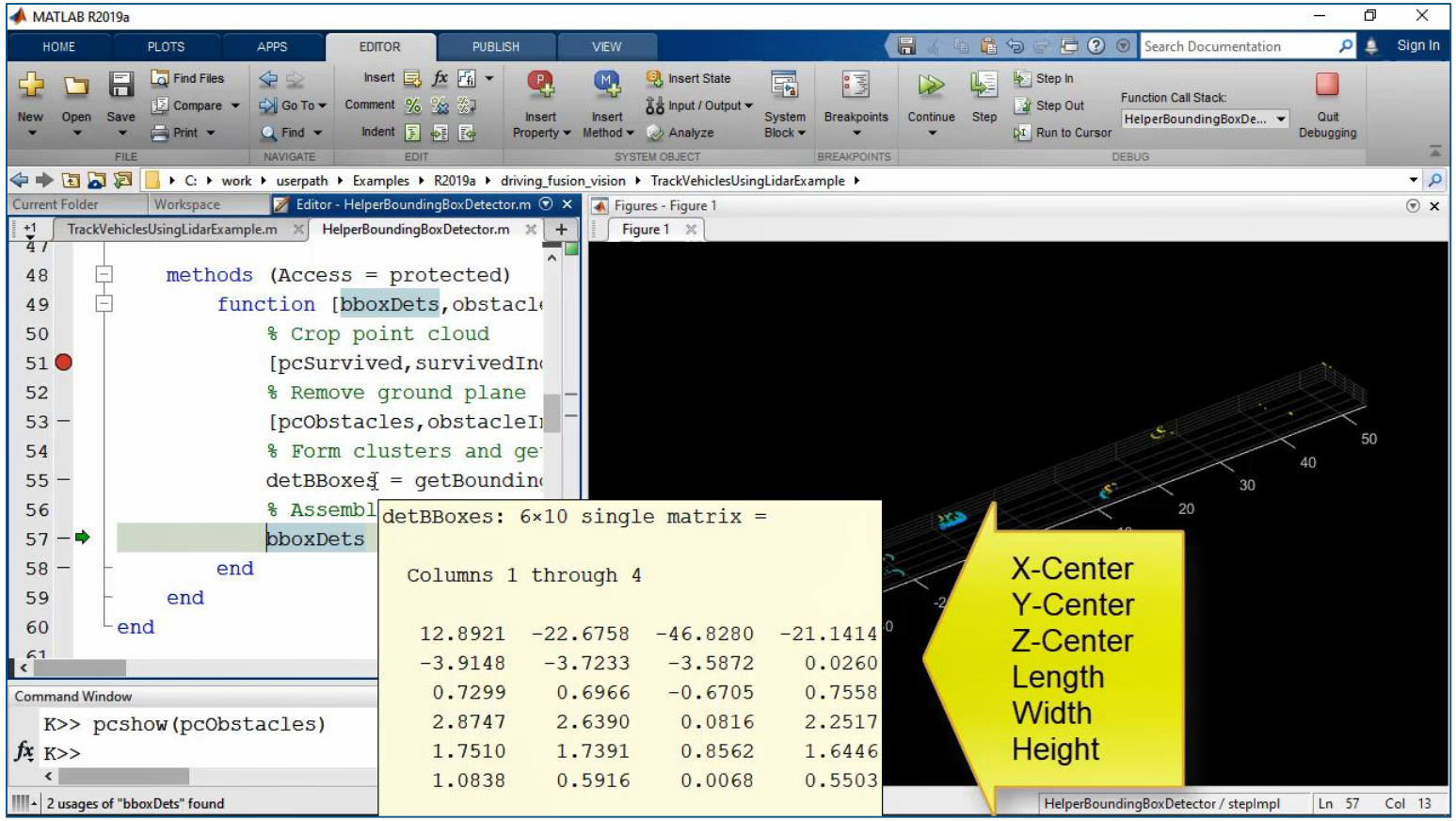
[Track Vehicles Using Lidar: From Point Cloud to Track List]

- 设计3-D边框检测器
- 设计目标跟踪器
- 生成C/C++代码

Sensor Fusion and Tracking Toolbox™

Computer Vision Toolbox™

R2019a



将激光雷达点云转换为目标列表：设计跟踪器

[Track Vehicles Using Lidar: From Point Cloud to Track List]

- 设计3-D边框检测器
- 设计目标跟踪器
- 生成C/C++代码

Sensor Fusion and Tracking Toolbox™

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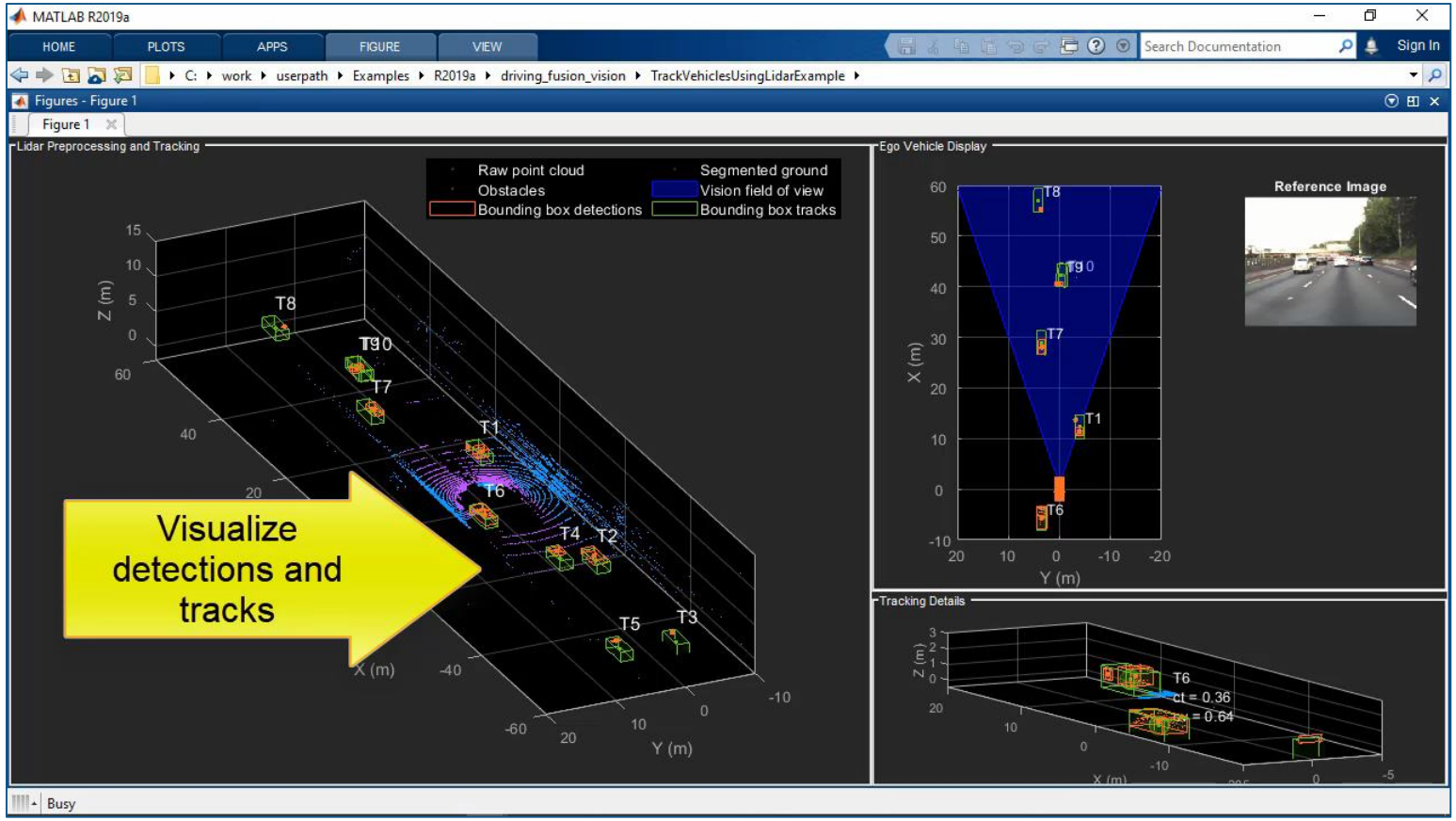

将激光雷达点云转换为目标列表：生成代码

[Track Vehicles Using Lidar: From Point Cloud to Track List]

- 设计3-D边框检测器
- 设计目标跟踪器
- 生成C/C++代码

Sensor Fusion and Tracking Toolbox™

Computer Vision Toolbox™

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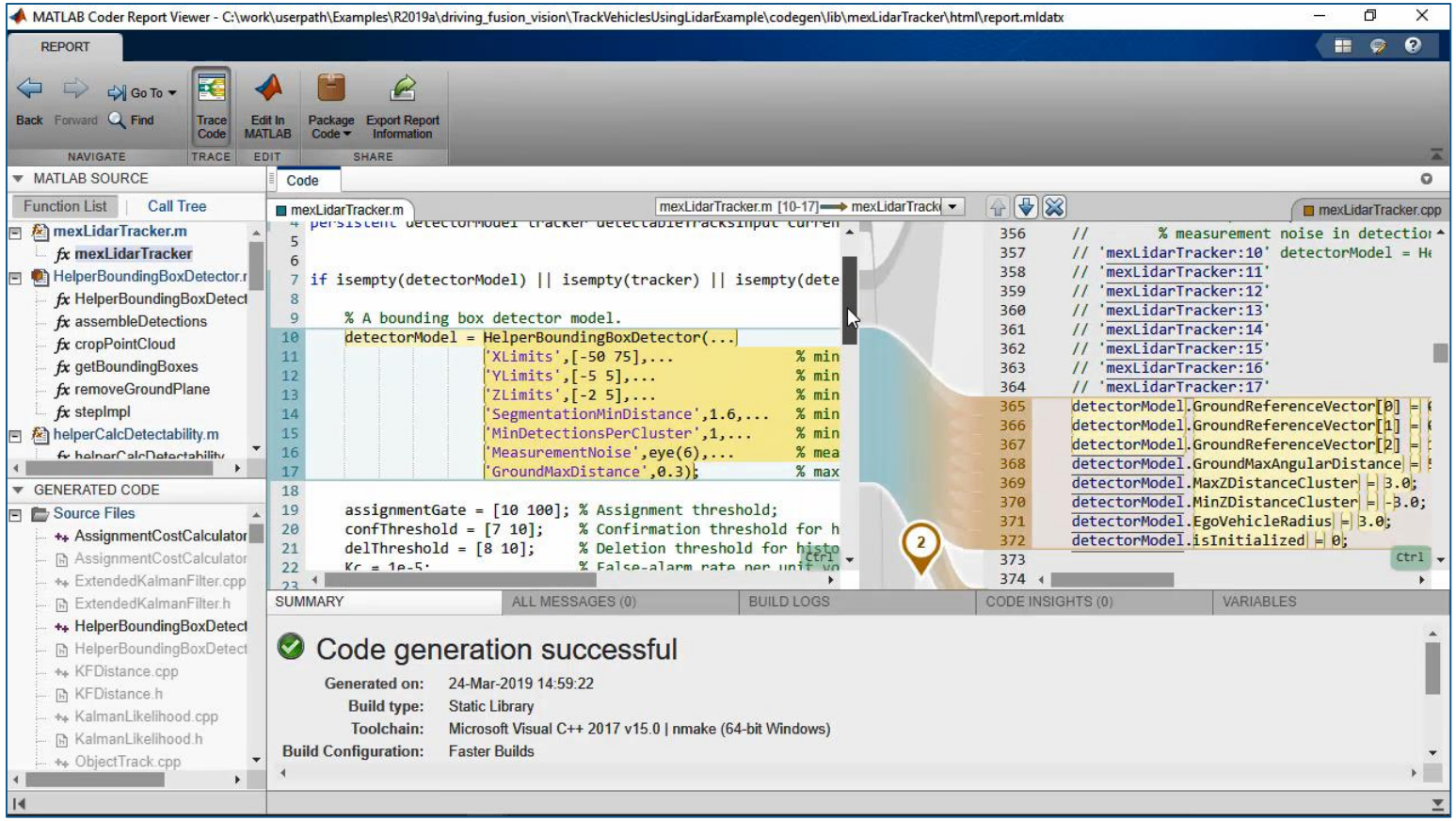


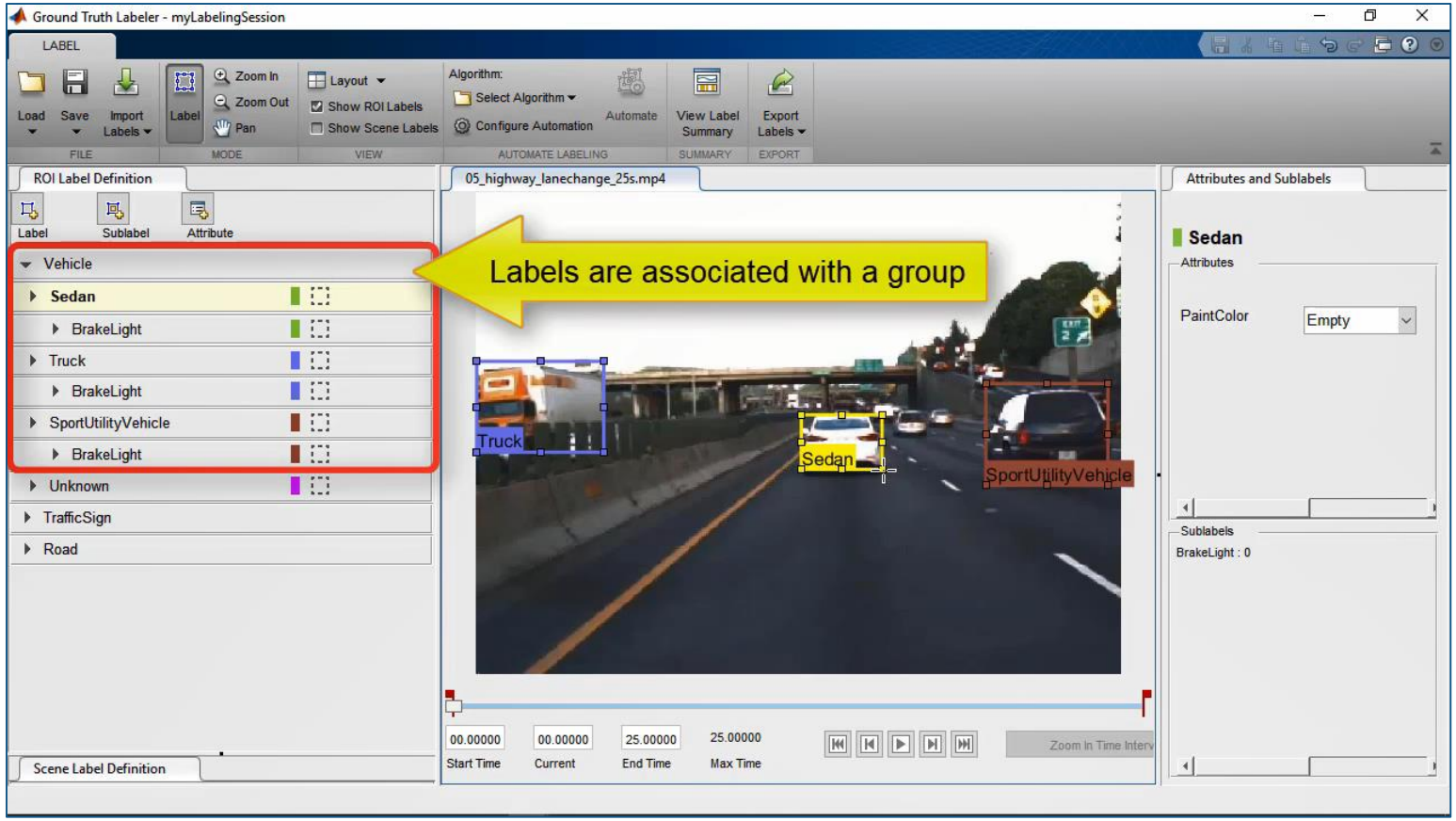
真值标签工具：创建选区标签与分组

[Get Started with the Ground Truth Labeler]

- 矩形框标签
- 多段线标签
- 像素标签
- 场景标签
- 创建标签分组
- 创建子标签
- 添加标签属性

Automated Driving Toolbox™

Updated R2019a



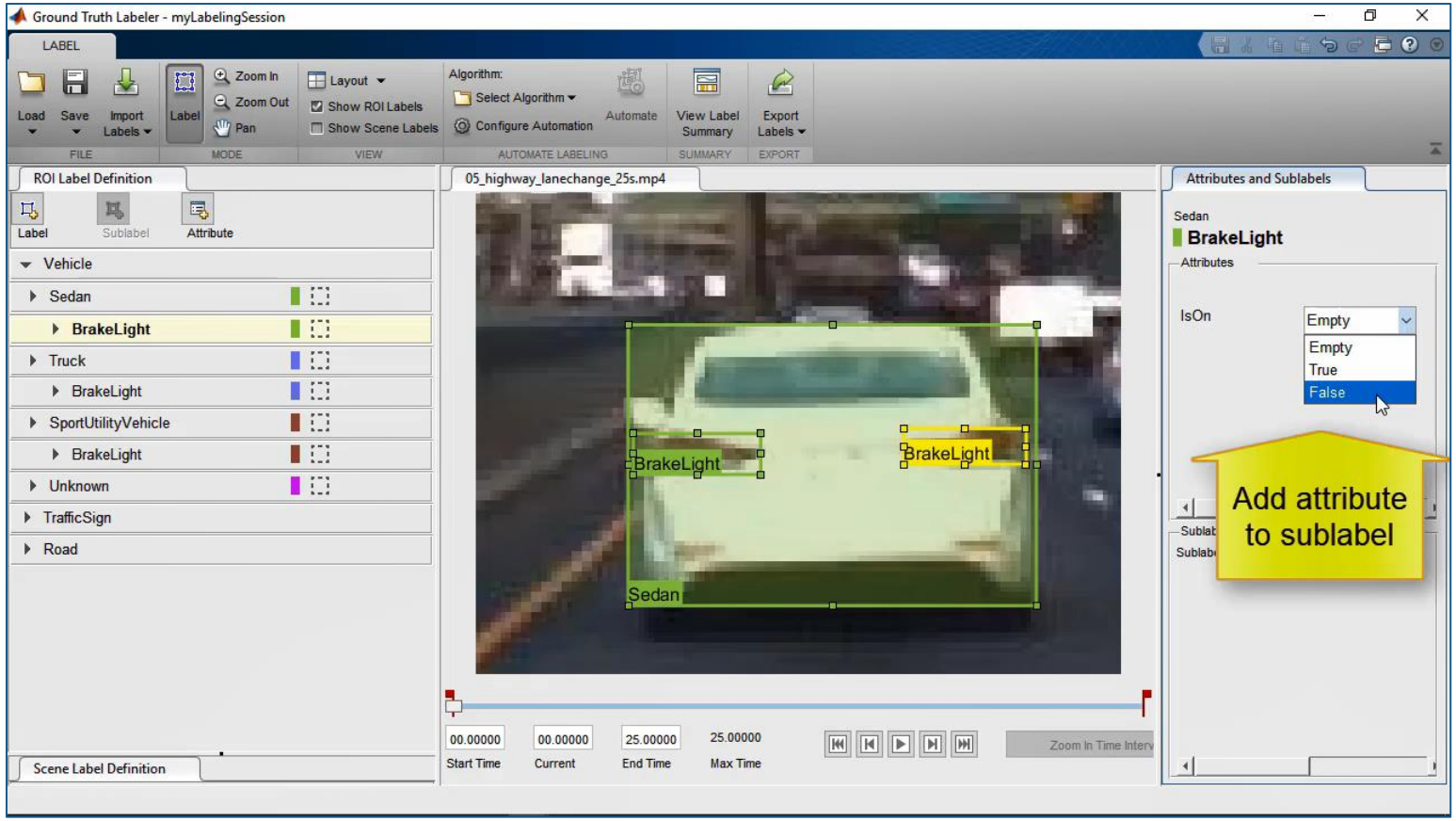
真值标签工具：创建子标签并添加属性

[Get Started with the Ground Truth Labeler]

- 矩形框标签
- 多段线标签
- 像素标签
- 场景标签
- 创建标签分组
- 创建子标签
- 添加标签属性

Automated Driving Toolbox™

Updated R2019a



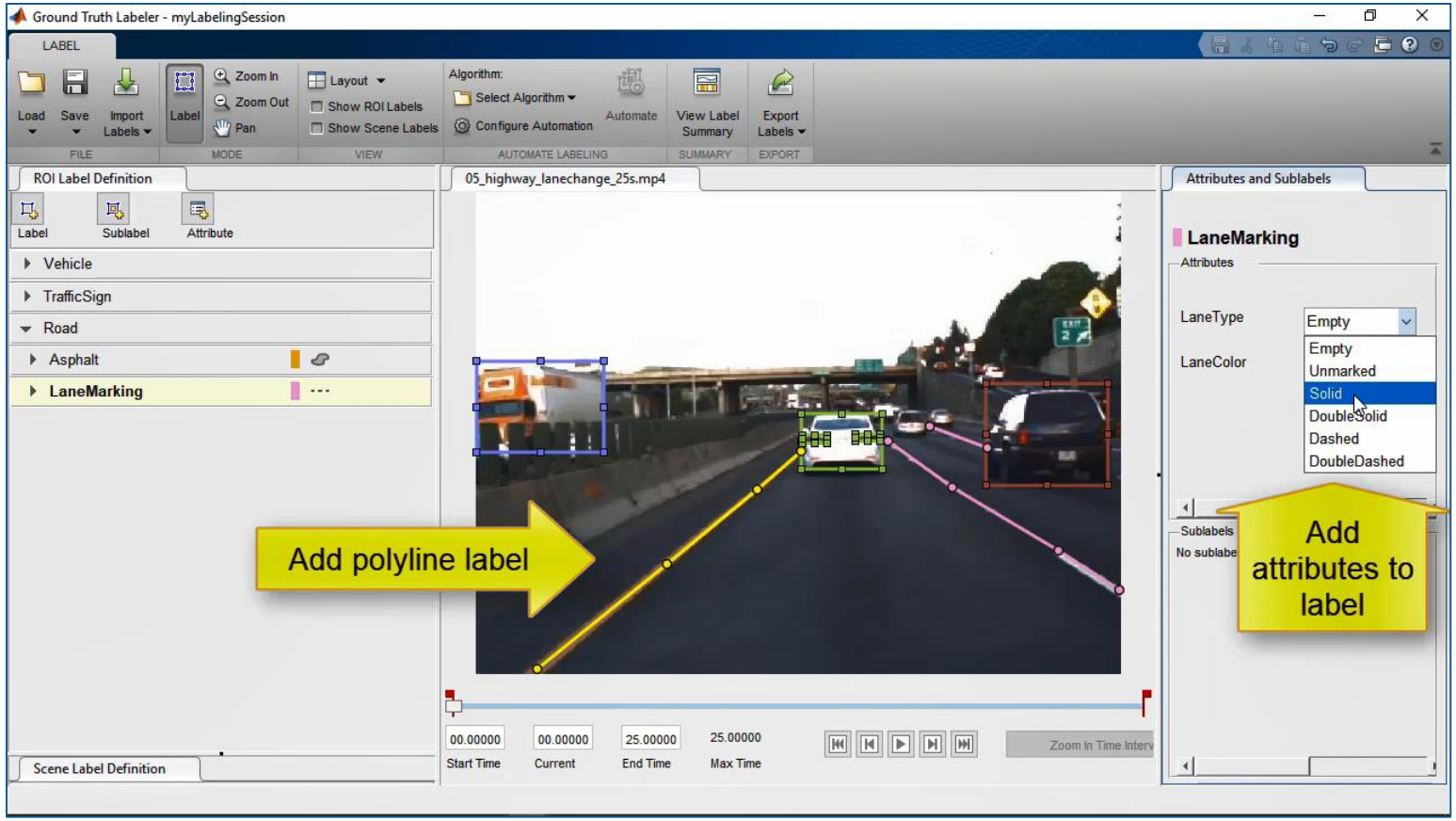
真值标签工具：创建多段线标签并添加属性

[Get Started with the Ground Truth Labeler]

- 矩形框标签
- 多段线标签
- 像素标签
- 场景标签
- 创建标签分组
- 创建子标签
- 添加标签属性

Automated Driving Toolbox™

Updated R2019a



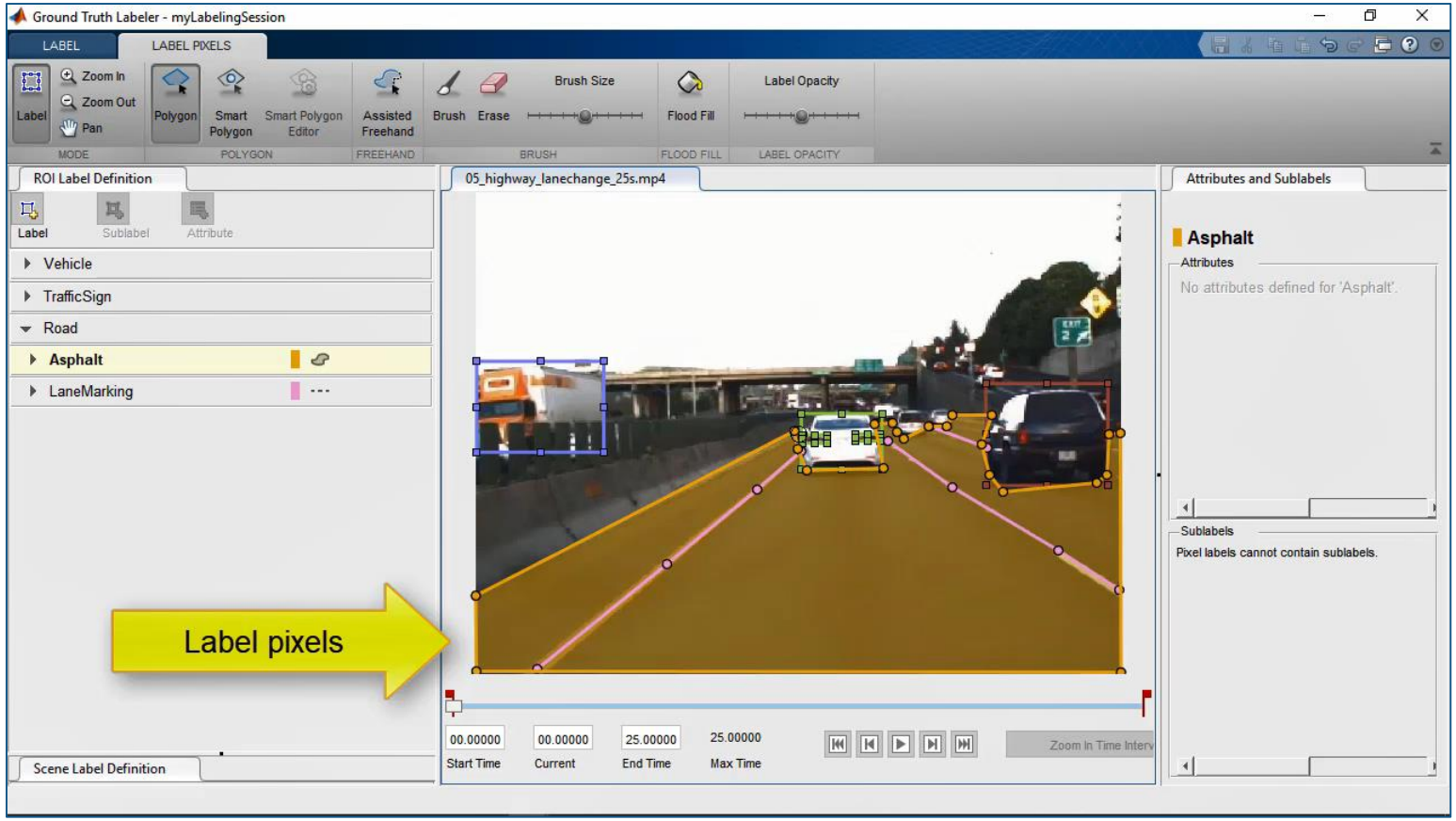
真值标签工具：创建像素标签

[Get Started with the Ground Truth Labeler]

- 矩形框标签
- 多段线标签
- 像素标签
- 场景标签
- 创建标签分组
- 创建子标签
- 添加标签属性

Automated Driving Toolbox™

Updated R2019a



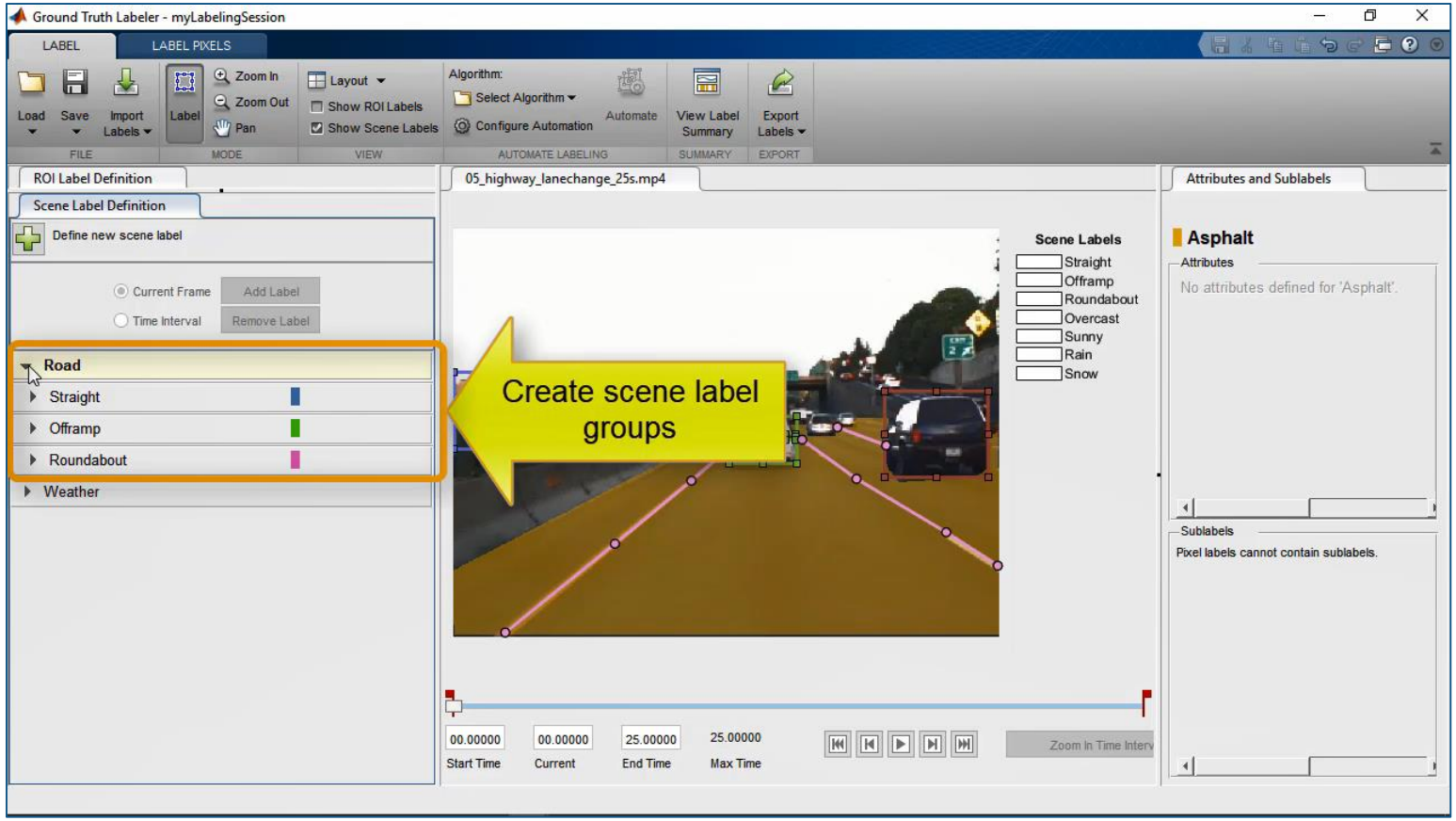
真值标签工具：创建场景标签与分组

[Get Started with the Ground Truth Labeler]

- 矩形框标签
- 多段线标签
- 像素标签
- 场景标签
- 创建标签分组
- 创建子标签
- 添加标签属性

Automated Driving Toolbox™

Updated R2019a



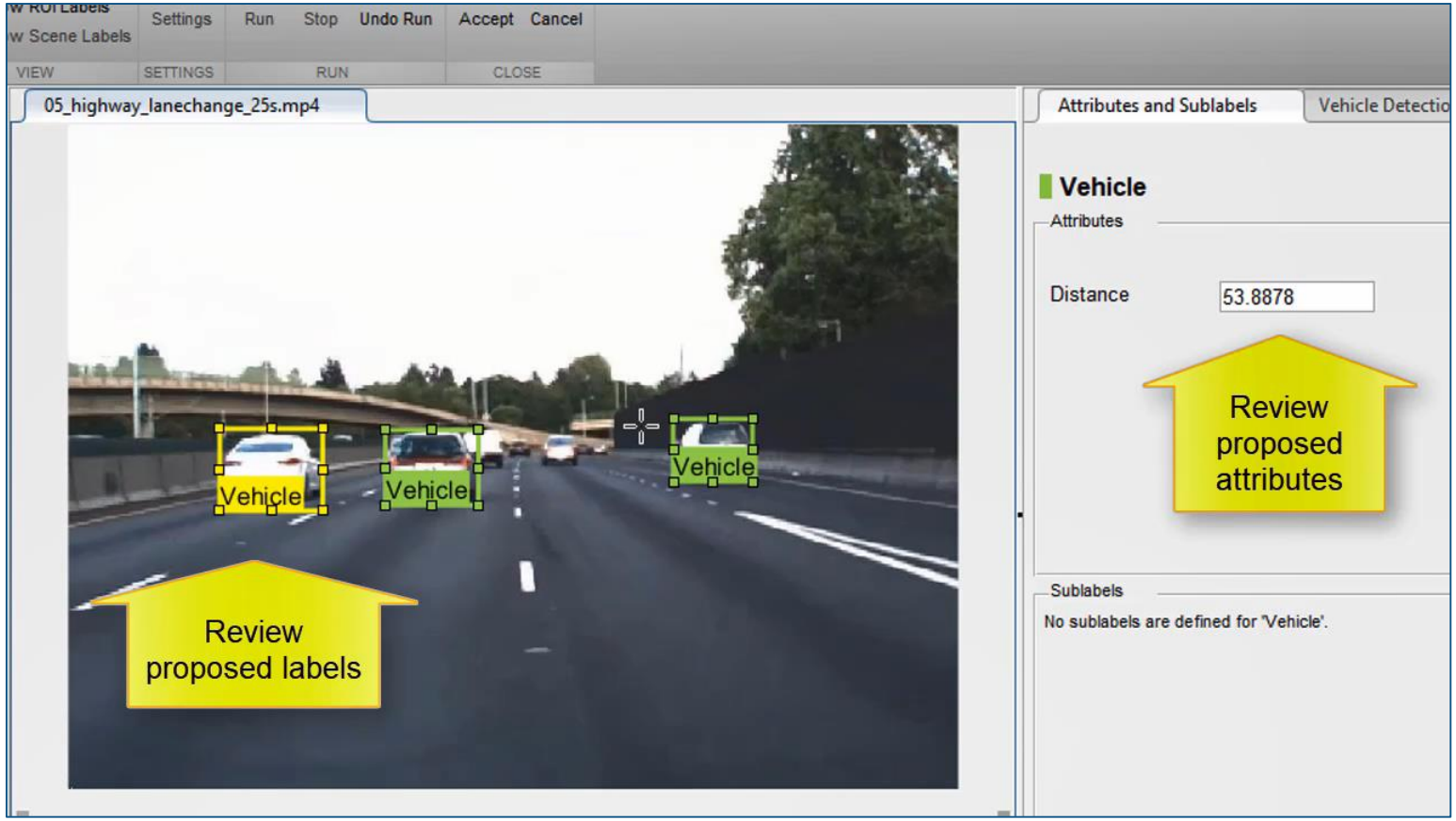
真值标签工具：导入自定义的自动标注算法

[Automate Attributes of Labeled Objects]

- 在真值标签工具中导入自动标注算法
- 在单目摄像机视图中检测车辆
- 估计检测到车辆的距离
- 运行自动标注算法并确认标签和属性

Automated Driving Toolbox™

R2018b



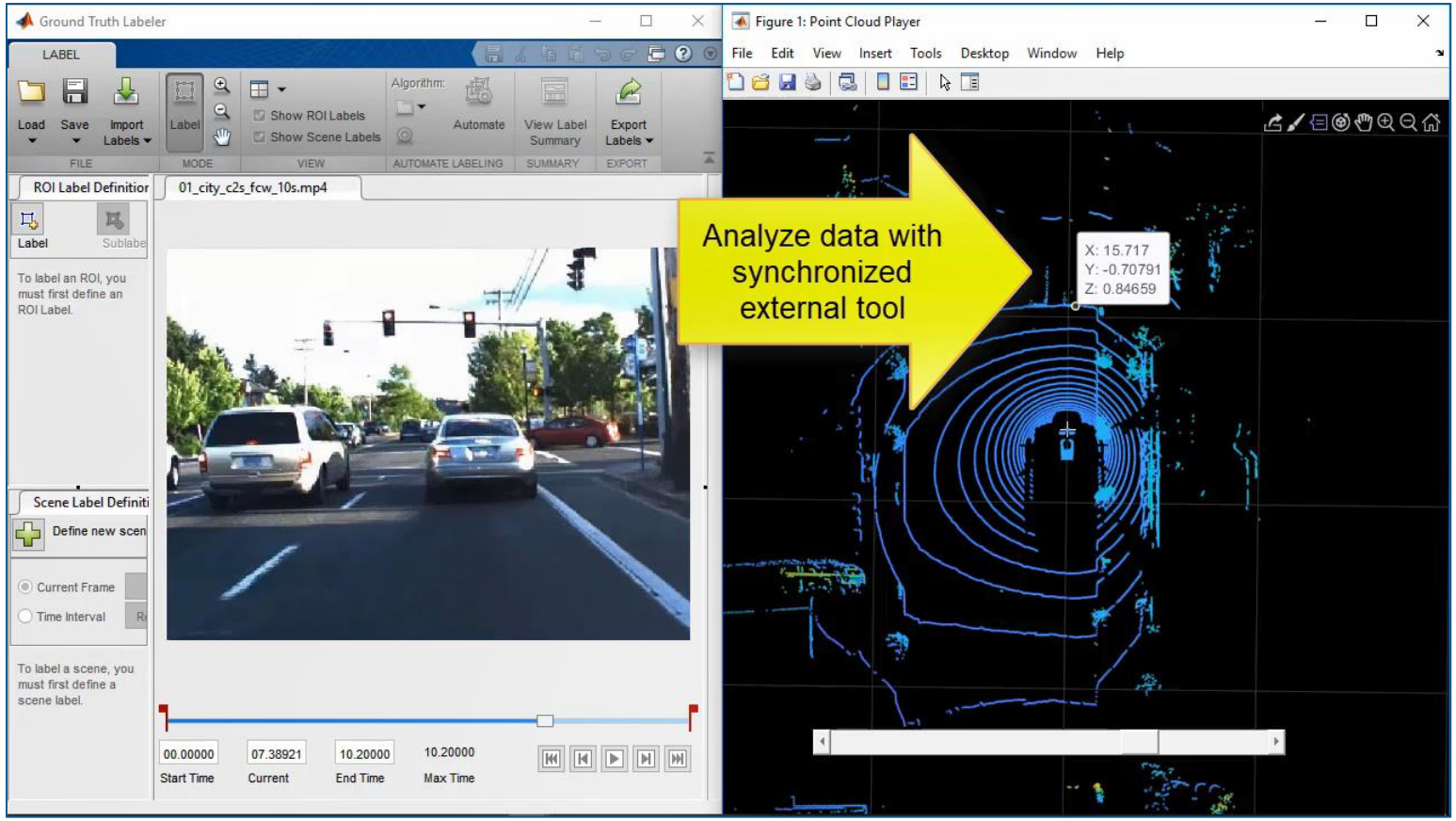
真值标签工具：添加自定义的多传感器视图

Connect Lidar Display to Ground Truth Labeler

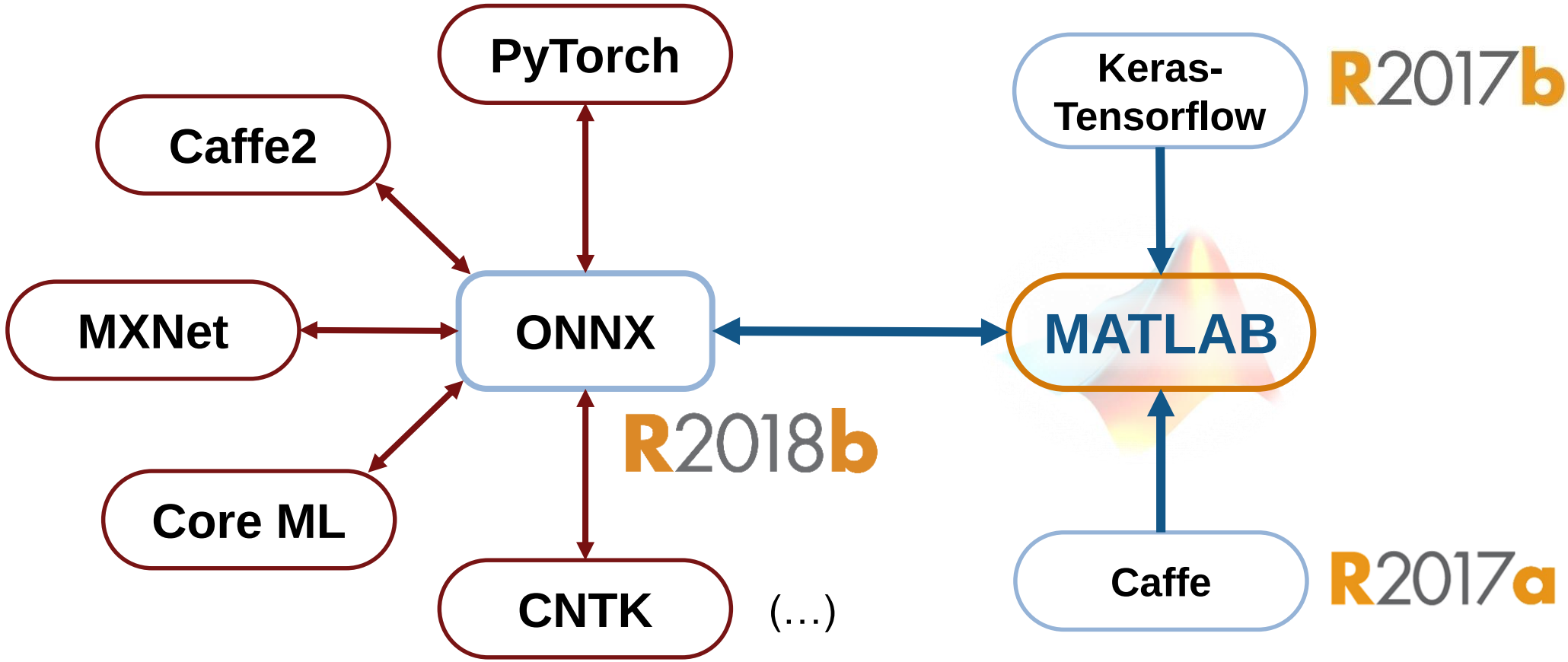
- 同步显示每一个数据帧
- 回放控制与数据分析

Automated Driving Toolbox™

R2017a



通过ONNX与各种深度学习框架交互



Open Neural Network Exchange

设计摄像机/雷达/激光雷达感知算法

采用摄像机检测车辆

[Object Detection Using YOLO v2 Deep Learning]

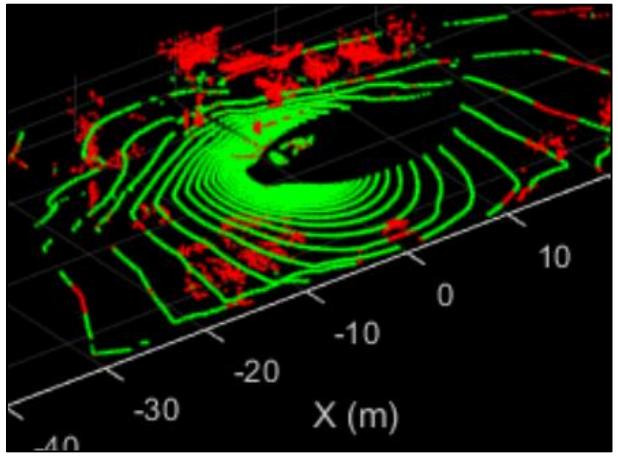
Computer Vision Toolbox™

Deep Learning Toolbox™

R2019a

MATLAB EXPO 2019

采用激光雷达检测地面

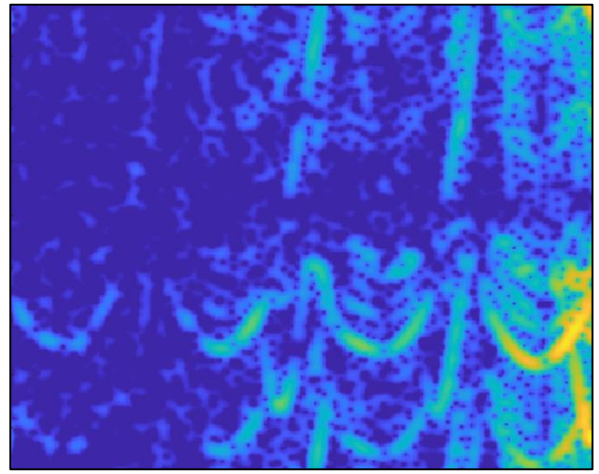


[Segment Ground Points from Organized Lidar Data]

Computer Vision Toolbox™

R2018b

采用雷达检测行人

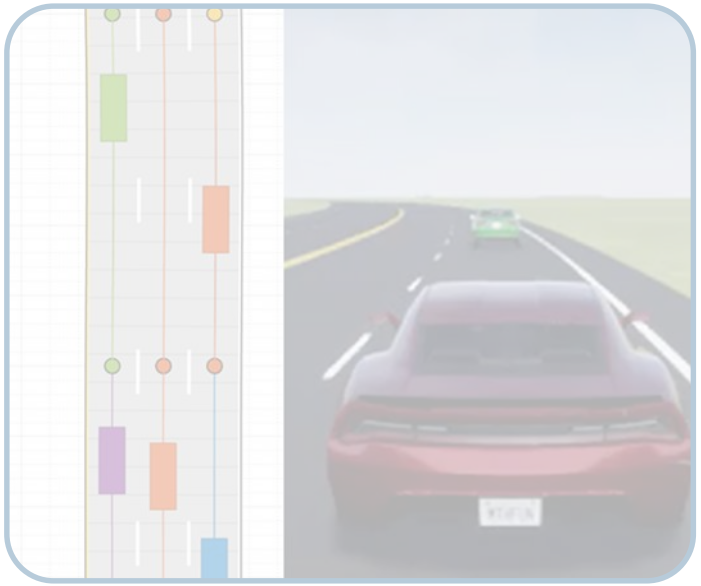


[Introduction to Micro-Doppler Effects]

Phased Array System Toolbox™

R2019a

自动驾驶工程师的几个常见问题



如何创建虚拟驾驶场景来测试我的设计？

如何串联和加速多个专业的算法开发？

如何将其他资源集成到我们的仿真环境？

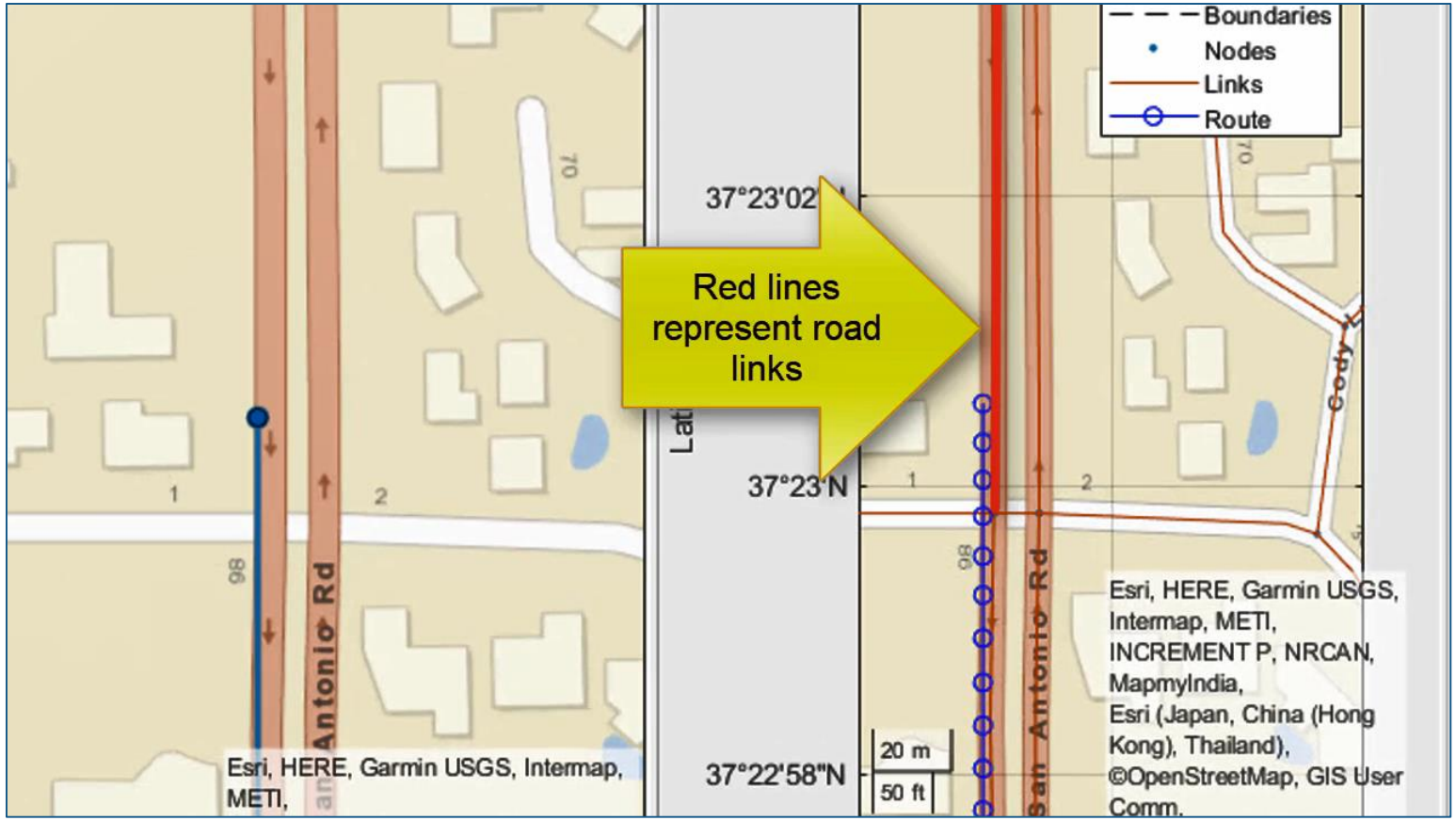
连接HERE高精度实时地图：读取道路和限速属性

[Use HERE HD Live Map Data to Verify Lane Configurations]

- 载入摄像机与GPS数据
- 读取道路限速
- 读取车道配置
- 可视化组合数据

Automated Driving Toolbox™

R2019a



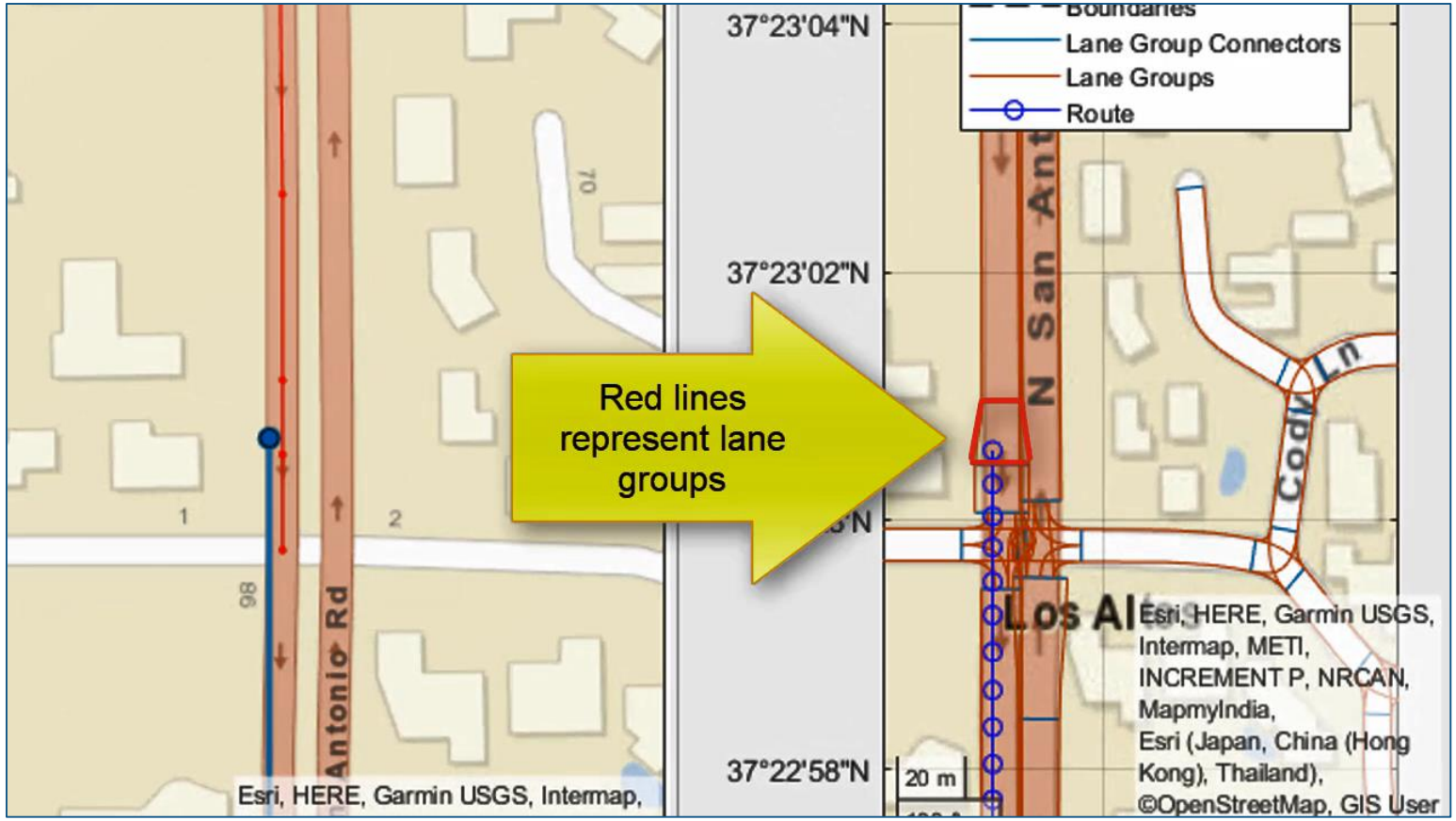
连接HERE高精度实时地图：读取车道属性

[Use HERE HD Live Map Data to Verify Lane Configurations]

- 载入摄像机与GPS数据
- 读取道路限速
- 读取车道配置
- 可视化组合数据

Automated Driving Toolbox™

R2019a



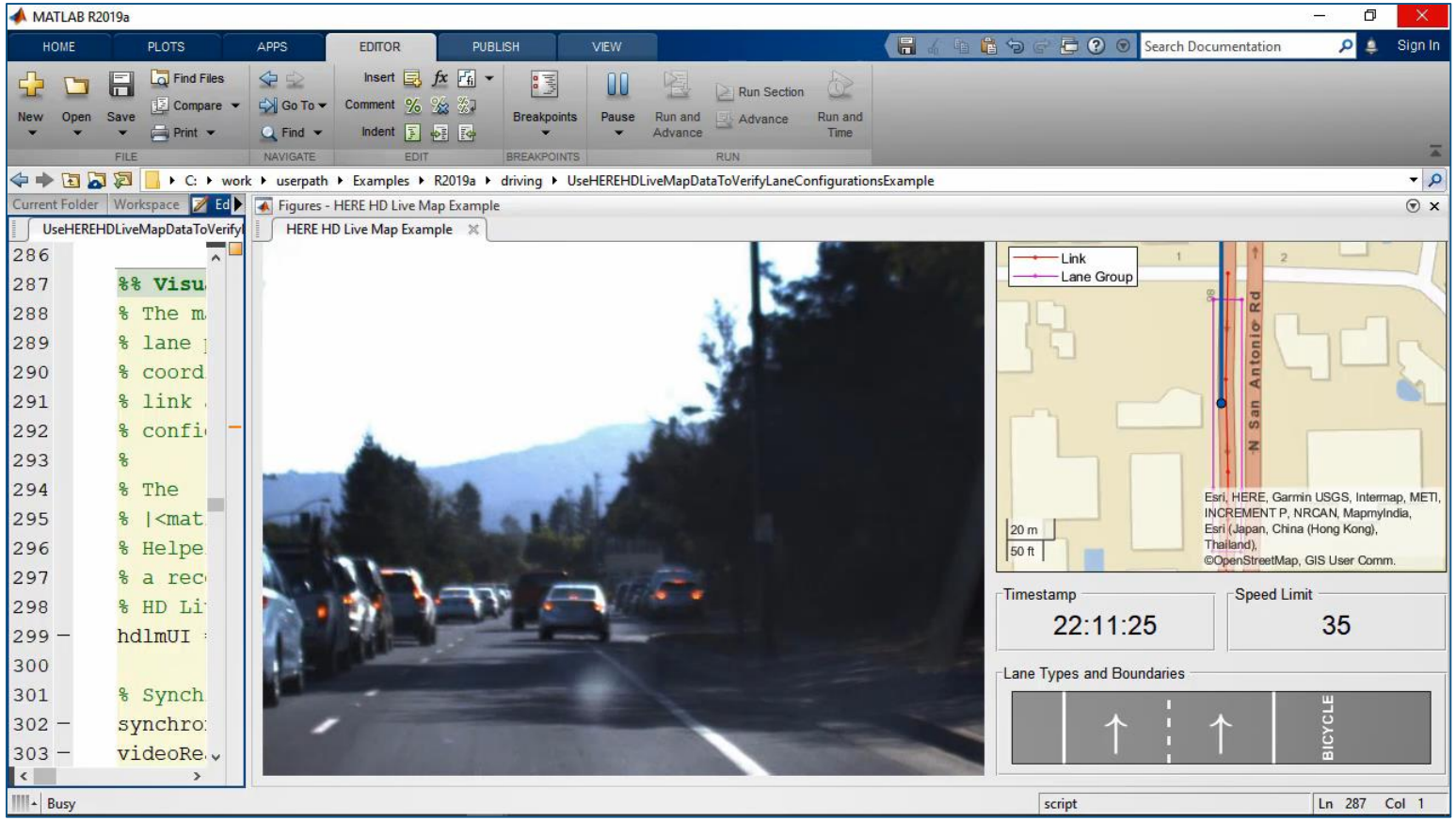
连接HERE高精度实时地图：可视化记录的数据

[Use HERE HD Live Map Data to Verify Lane Configurations]

- 载入摄像机与GPS数据
- 读取道路限速
- 读取车道配置
- 可视化组合数据

Automated Driving Toolbox™

R2019a



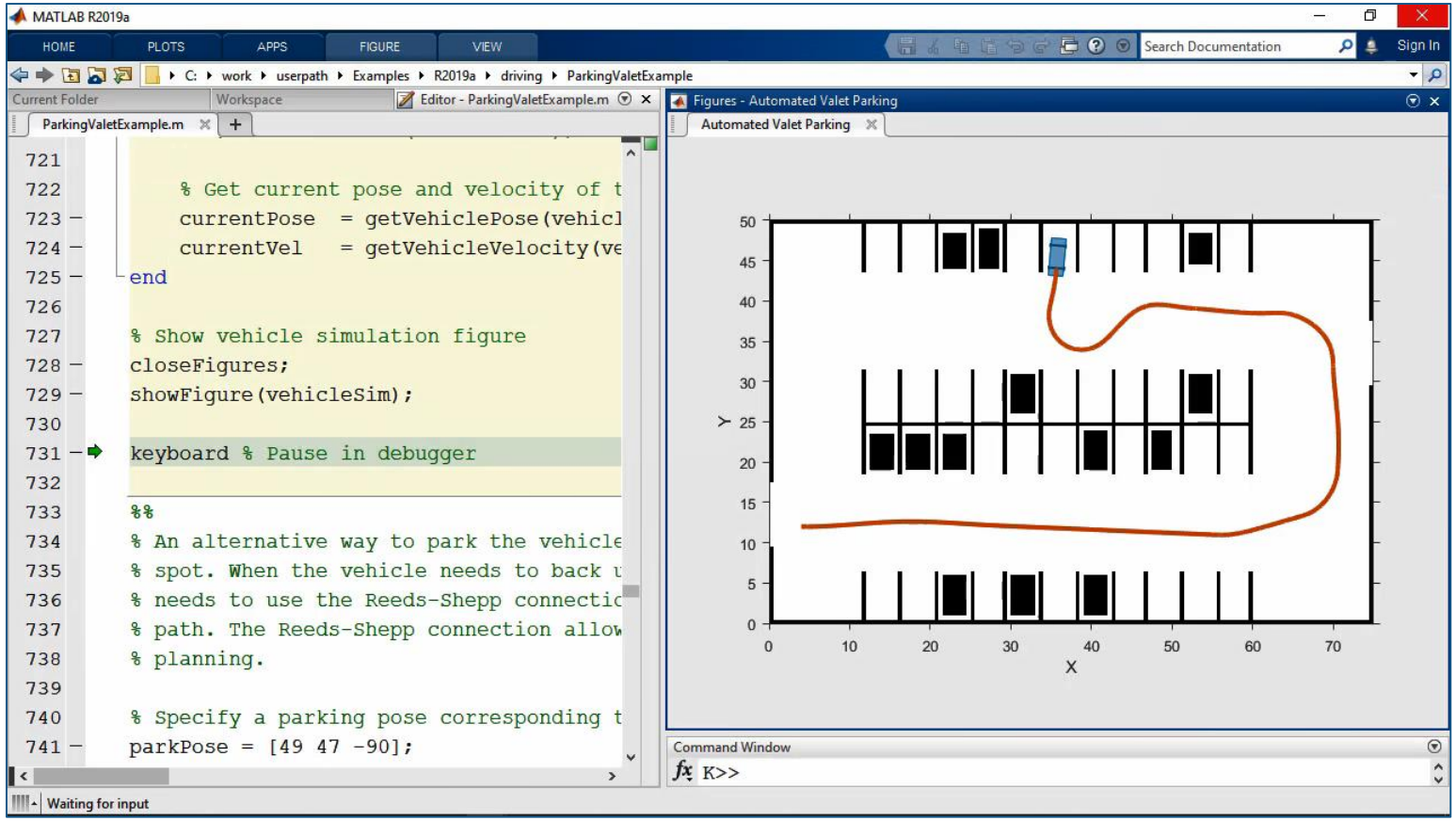
设计路径规划器

[Automated Parking Valet]

- 创建环境的代价地图
- 膨胀代价地图用于碰撞检测
- 指定目标位置
- 使用快速搜索随机树 (RRT*) 算法规划路径

Automated Driving Toolbox™

R2018a



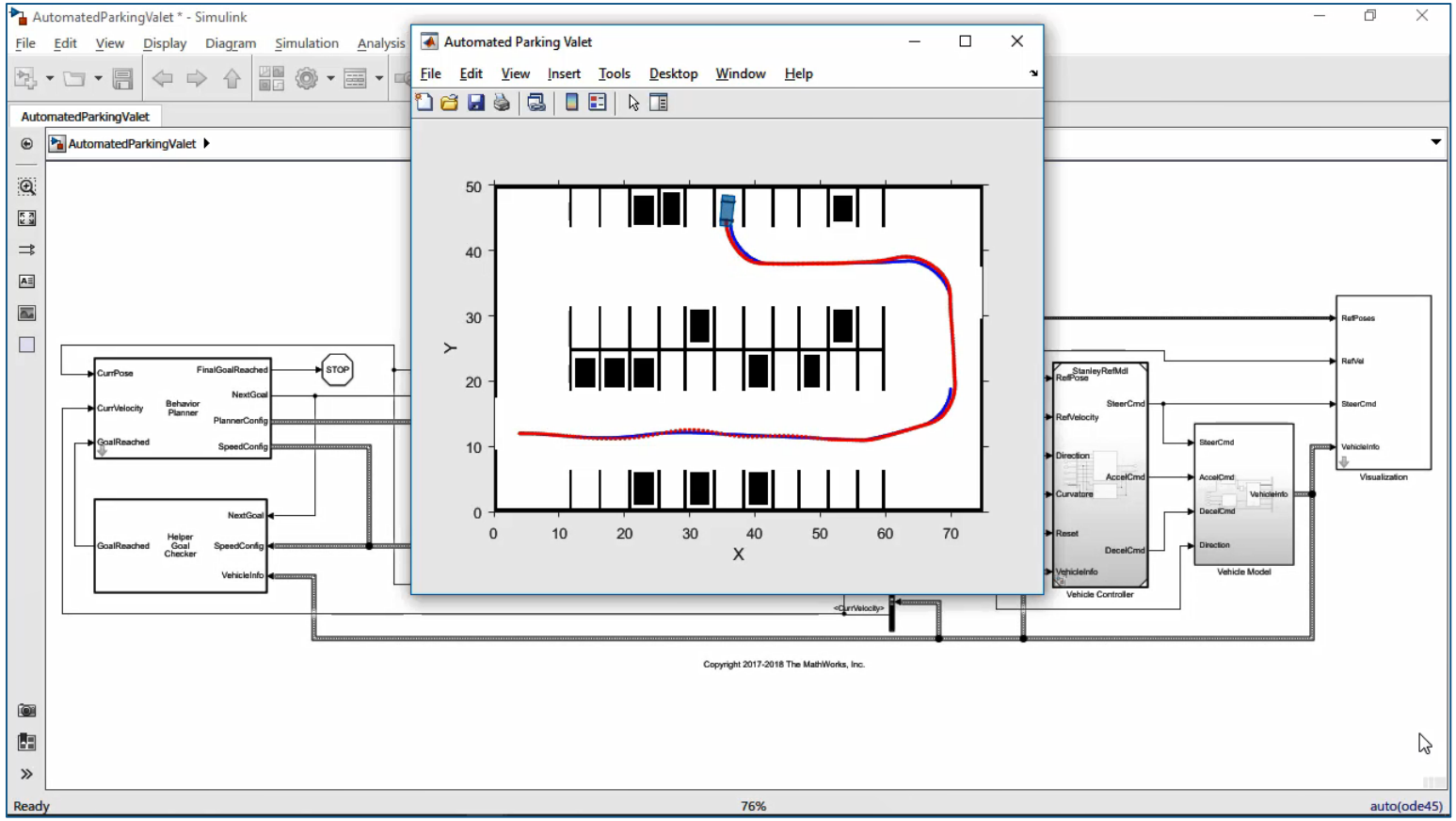
设计路径规划器与车辆控制器

[Automated Parking Valet with Simulink]

- 路径规划器（RRT*算法）
- 车辆横向与纵向控制器（基于运动学的Stanley算法）
- 与车辆动力学模型结合进行闭环仿真

Automated Driving Toolbox™

R2018b



规划与控制算法生成C/C++代码

[Code Generation for Path Planning and Vehicle Control]

- 独立的模型文件
- 配置代码生成选项
- 生成C/C++代码
- 软件在环 (SIL) 测试
- 评估代码执行时间

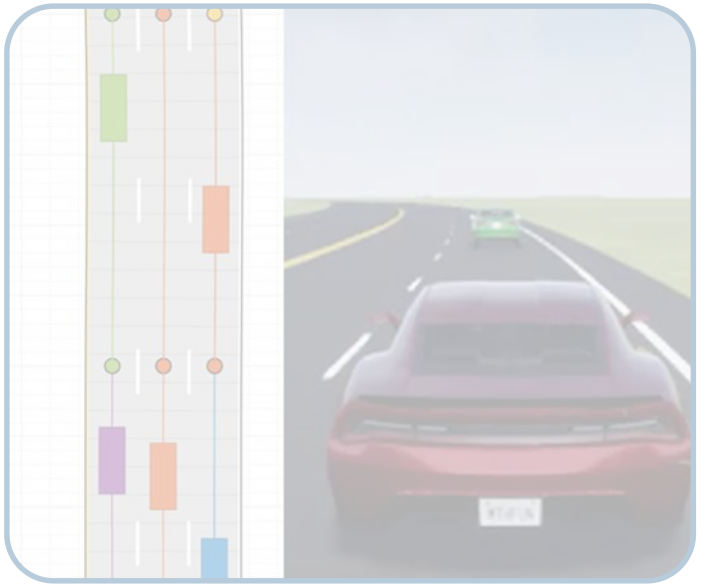
Automated Driving Toolbox™

Embedded Coder™

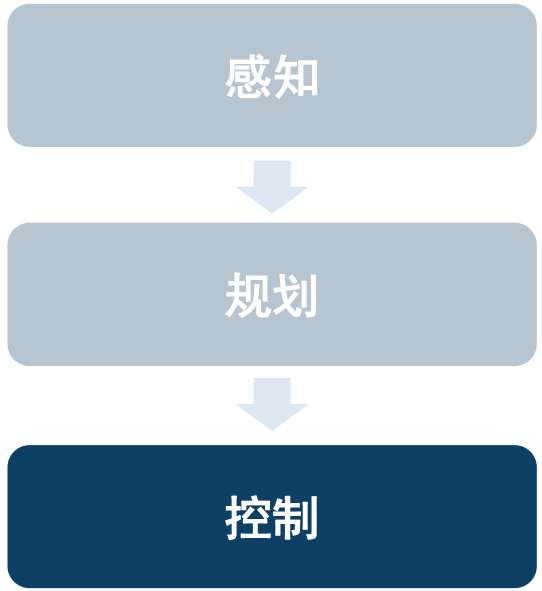
R2019a

```
186
187   // model step function
188   void step0();
189
190   // model step function
191   void step1();
192
193   // model terminate function
194   void terminate();
195
196   // Constructor
197   AutomatedParkingValetModelClass();
198
199   // Destructor
200   ~AutomatedParkingValetModelClass();
201
202   // Root inport: '<Root>/Costmap' set method
203   void setCostmap(costmapBus localArgInput);
204
205   // Root inport: '<Root>/GoalPose' set method
206   void setGoalPose(real_T localArgInput[3]);
207
```

自动驾驶工程师的几个常见问题



如何创建虚拟驾驶场景来测试我的设计？

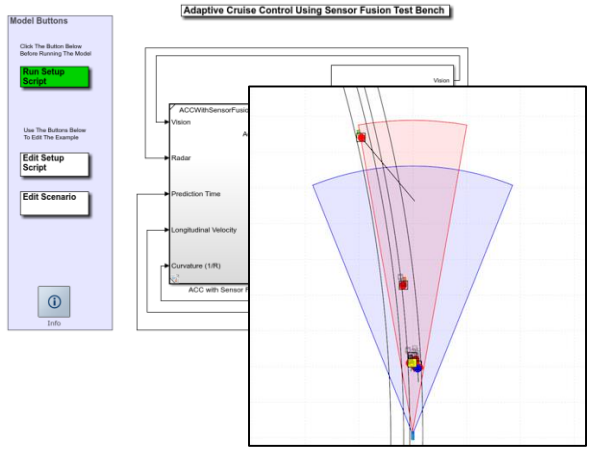


如何串联和加速多个专业的算法开发？

如何将其他资源集成到我们的仿真环境？

设计纵向与横向模型预测控制器

纵向控制



[Adaptive Cruise Control with Sensor Fusion]

Automated Driving Toolbox™

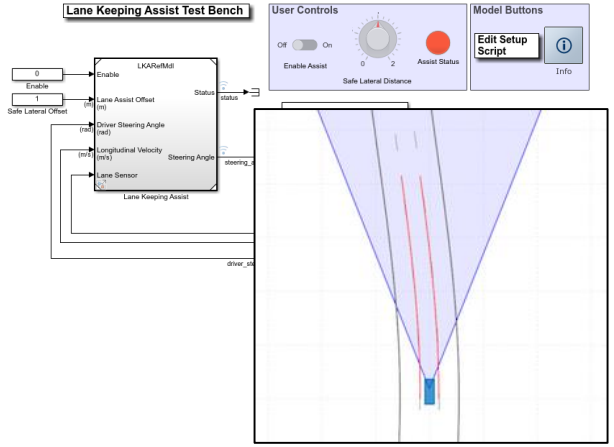
Model Predictive Control Toolbox™

Embedded Coder®

R2017b

MATLAB EXPO 2019

横向控制



[Lane Keeping Assist with Lane Detection]

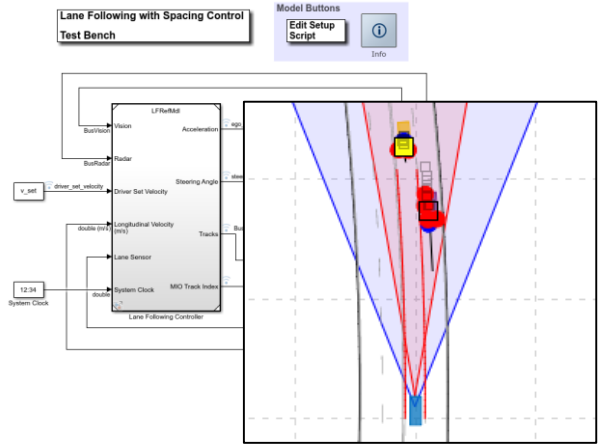
Automated Driving Toolbox™

Model Predictive Control Toolbox™

Embedded Coder®

R2018a

纵向 + 横向



[Lane Following Control with Sensor Fusion and Lane Detection]

Automated Driving Toolbox™

Model Predictive Control Toolbox™

Embedded Coder®

R2018b

通过闭环仿真设计实际的ADAS功能

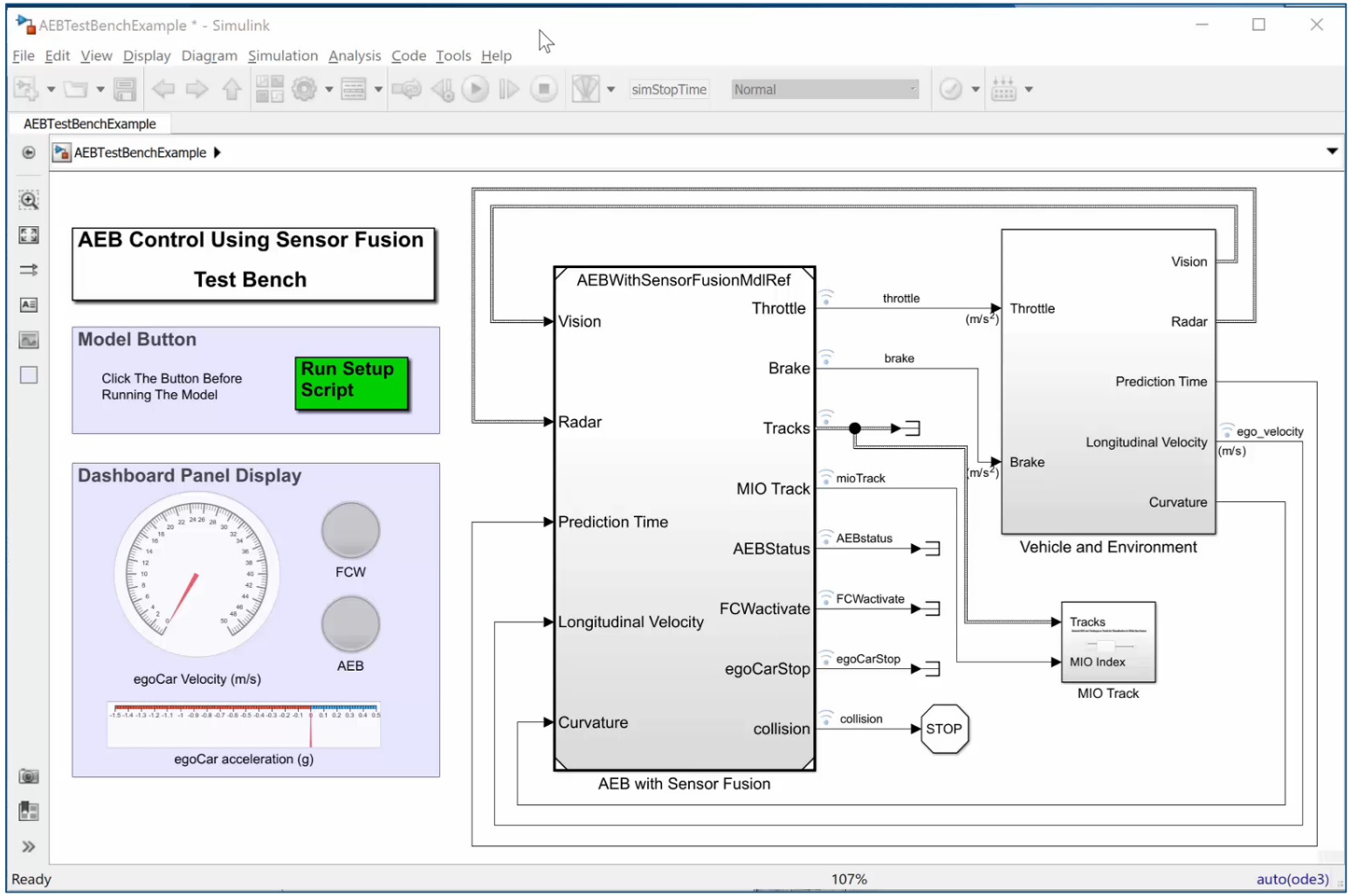
[Automatic Emergency Braking (AEB) with Sensor Fusion]

- 指定驾驶场景
- 设计AEB逻辑
- 设计传感器融合算法
- 仿真完整系统
- 生成C/C++代码
- 软件在环 (SIL) 测试

Automated Driving Toolbox™

Stateflow®

Embedded Coder®



R2018b

MATLAB EXPO 2019

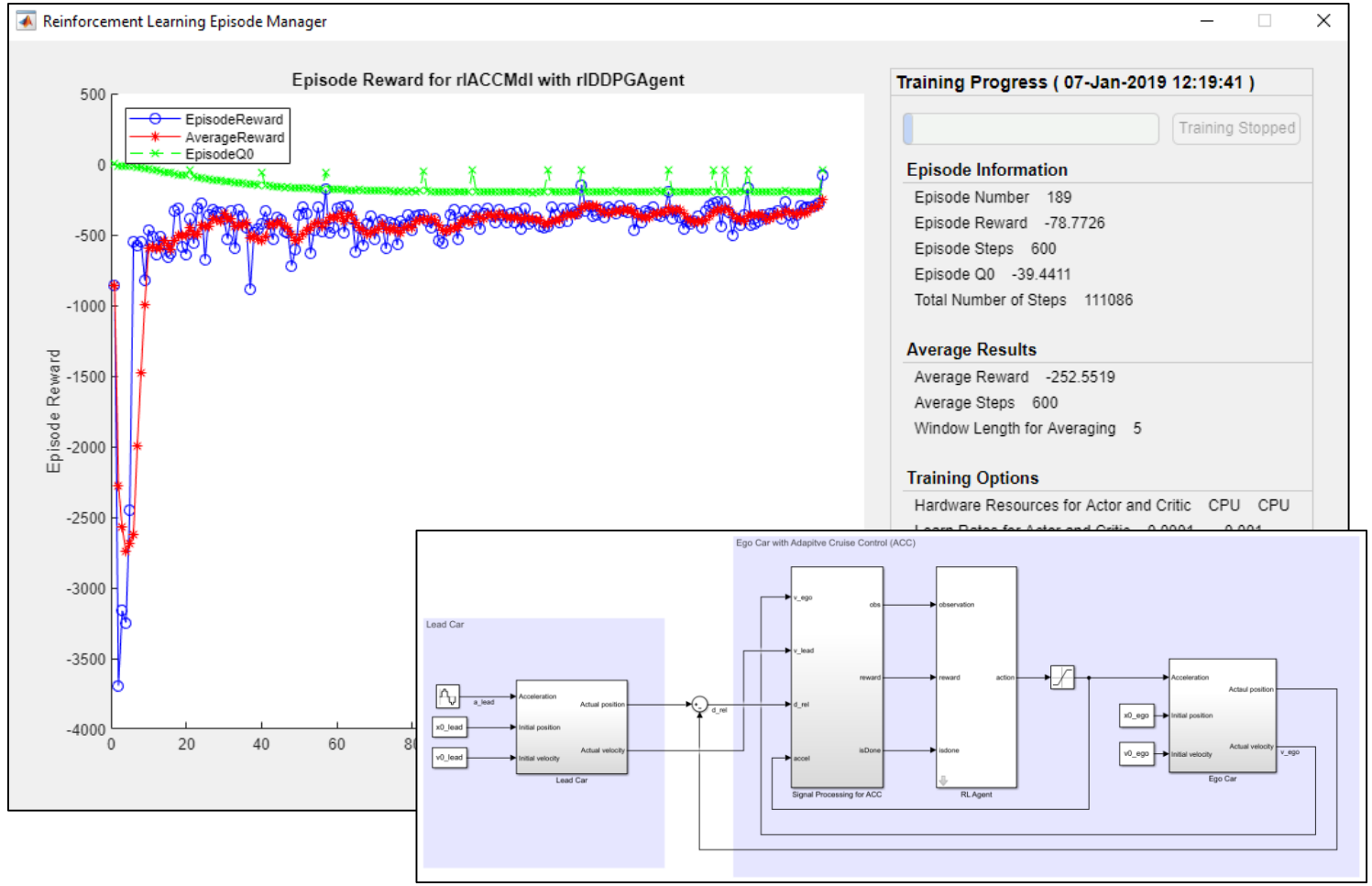
训练用于ADAS控制的增强学习网络

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

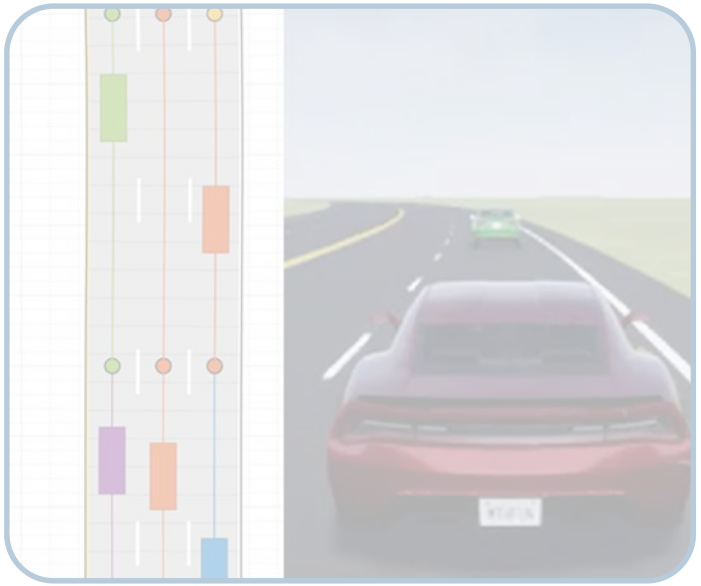
- 创建环境接口
- 创建agent
- 训练agent
- 仿真训练的agent

Reinforcement Learning Toolbox™

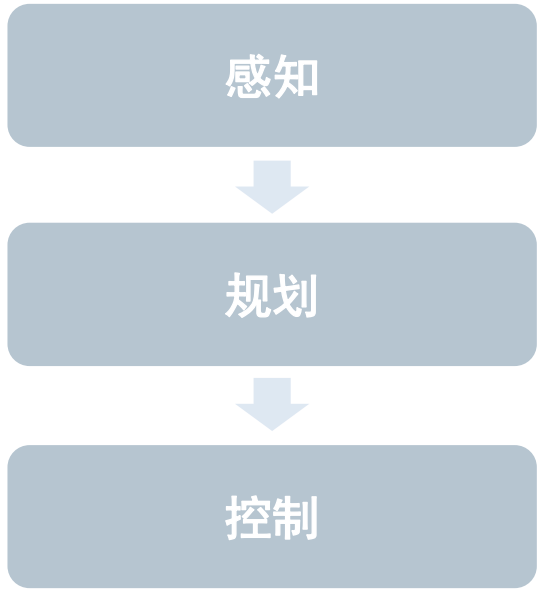
R2019a



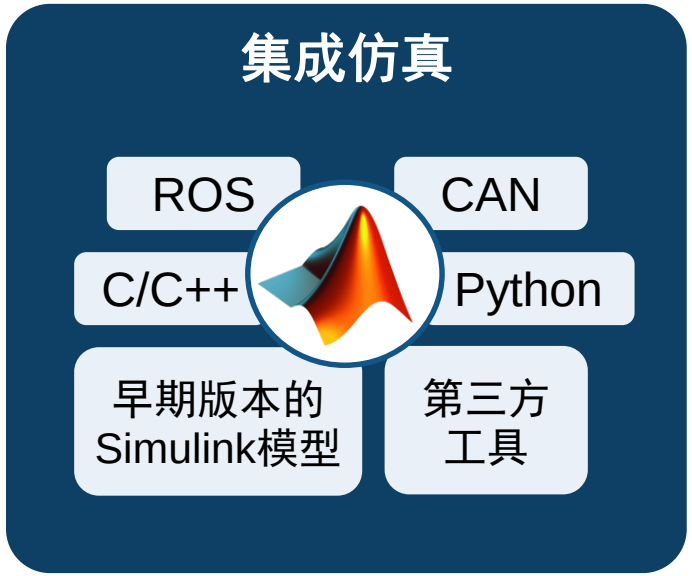
自动驾驶工程师的几个常见问题



如何创建虚拟驾驶场景来测试我的设计？



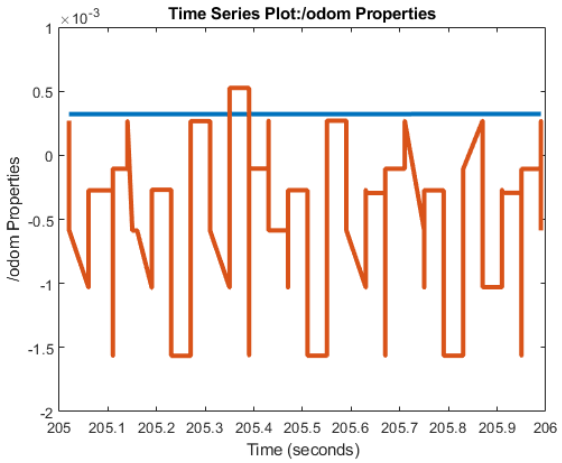
如何串联和加速多个专业的算法开发？



如何将其他资源集成到我们的仿真环境？

与ROS集成的三种方式

回放通过ROS记录的数据

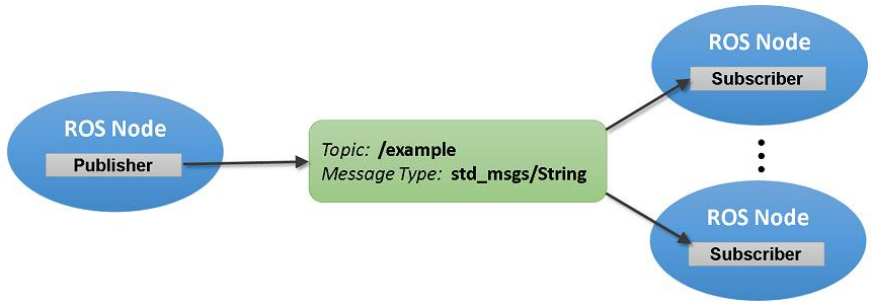


[Work with rosbag Logfiles]

Robotics System Toolbox™

Updated **R2018a**

实时连接ROS系统

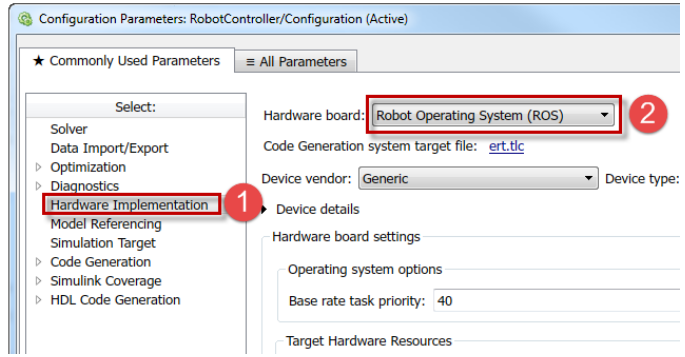


[Exchange Data with ROS Publishers and Subscribers]

Robotics System Toolbox™

R2016b

生成独立的ROS节点



[Generate a Standalone ROS Node from Simulink]

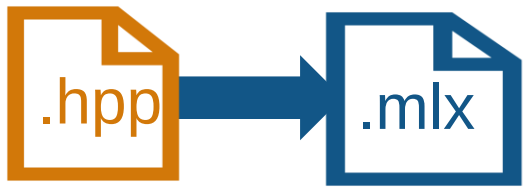
Robotics System Toolbox™

Simulink Coder™

R2016b

从MATLAB调用C++, Python, OpenCV

调用C++



[Import C++ Library Functionality into MATLAB]

MATLAB®

R2019a

调用Python

```
tw = ...
py.textwrap.TextWrapper(...
   pyargs(...
    'initial_indent',    '% ',...
    'subsequent_indent','% ',...
    'width', int32(30)))
```

[Call Python from MATLAB]

MATLAB®

R2014a

调用OpenCV & OpenCV GPU

```
cv::Rect
cv::KeyPoint
cv::Size
cv::Mat
cv::Ptr
...
```

[Install and Use Computer Vision Toolbox OpenCV Interface]

Computer Vision System Toolbox™

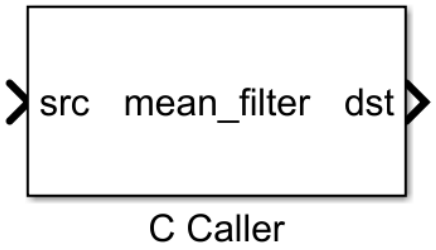
OpenCV Interface Support Package

Updated R2018b

MATLAB EXPO 2019

从Simulink调用C代码

调用C代码



[Bring Custom Image Filter Algorithms as Reusable Blocks in Simulink]

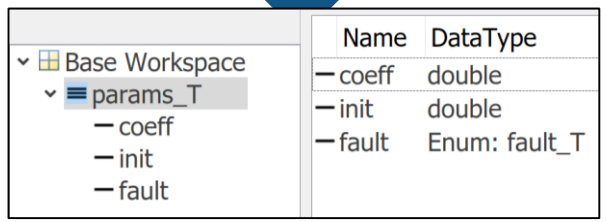
Simulink®

R2017b

MATLAB EXPO 2019

从C结构体创建Bus

```
typedef struct {
    double  coeff;
    double  init;
    fault_T fault;
} params_T;
```

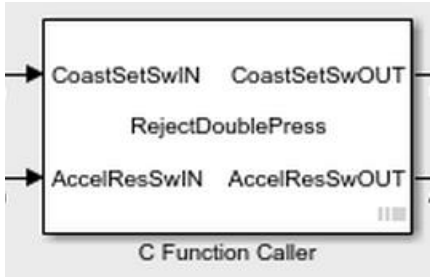


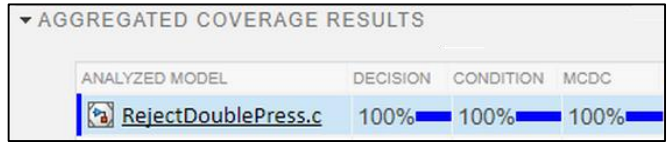
[Import Structure and Enumerated Types]

Simulink®

R2017a

测试与验证C代码





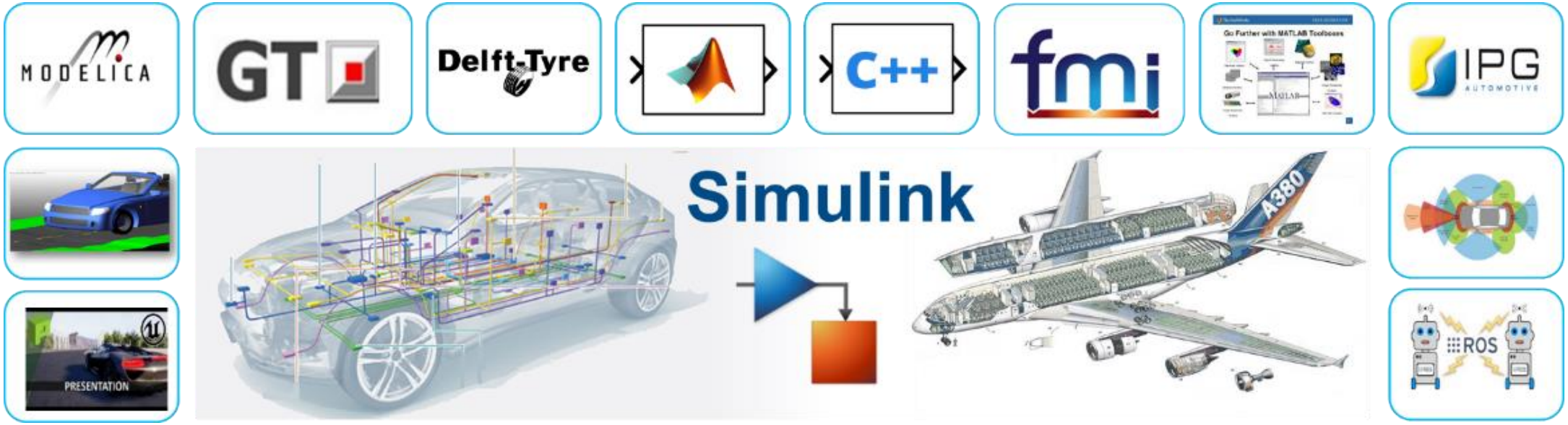
[Custom C Code Verification with Simulink Test]

Simulink Test™

Simulink Coverage™

R2019a

连接第三方工具



我们提供152种到第三方
建模与仿真工具的接口
(2019年3月统计)

MathWorks
Partner

通过代码生成，仿真早期版本模型

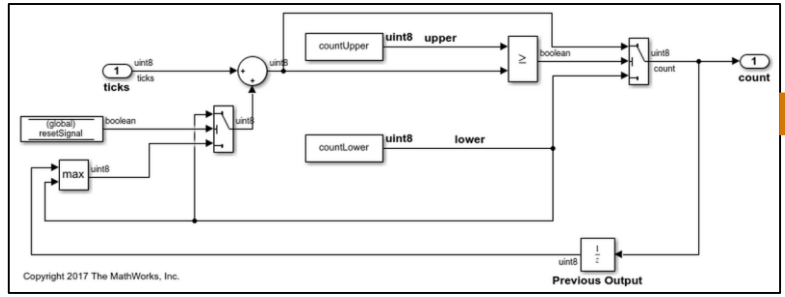
[Integrate Generated Code by Using Cross-Release Workflow]

- 从早期版本生成代码 (R2010a或以后版本)
- 在当前版本种导入生成的代码作为一个模块
- 允许调节参数
- 允许访问内部信号

Embedded Coder

R2016a

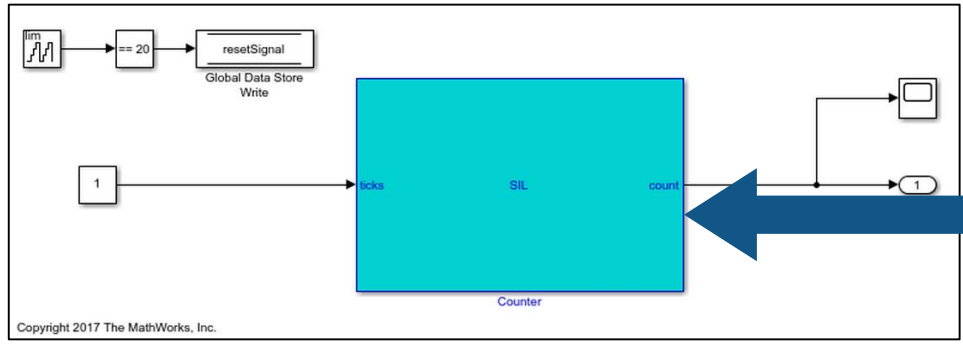
Previous Release



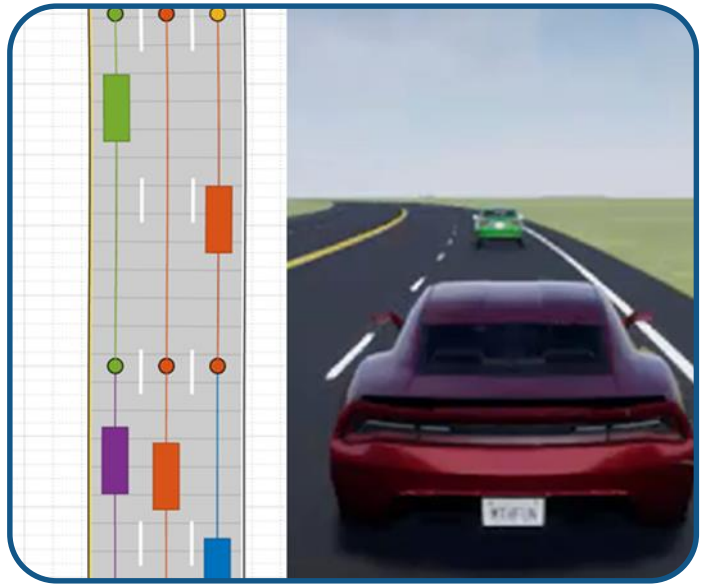
C

`crossReleaseImport`

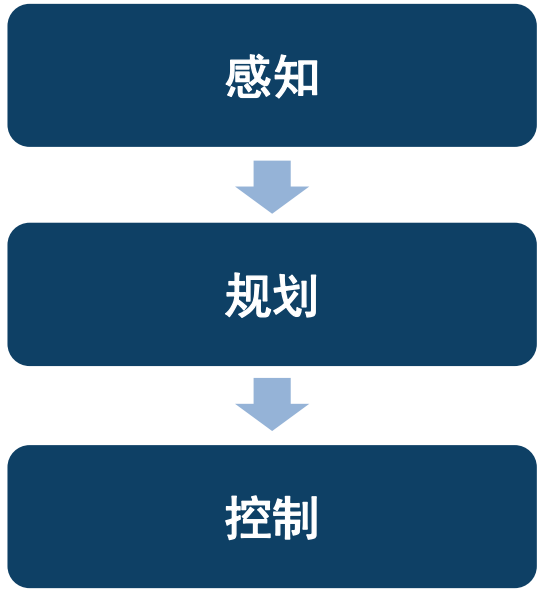
Current Release



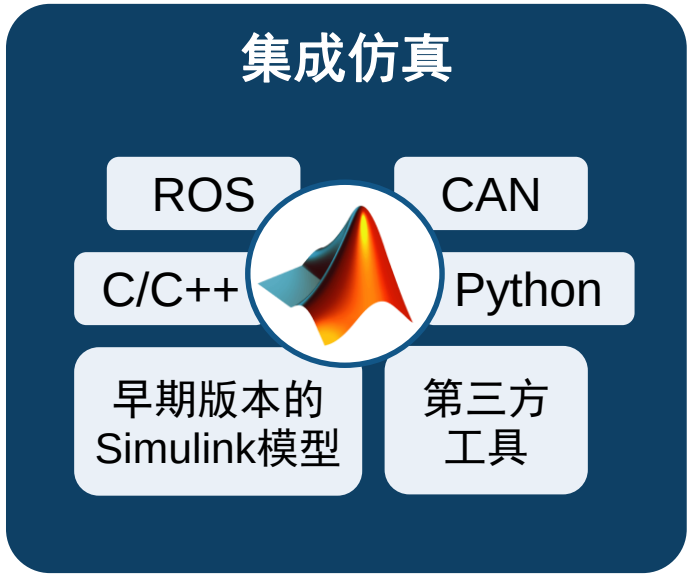
自动驾驶工程师的几个常见问题



如何创建虚拟驾驶场景来测试我的设计？

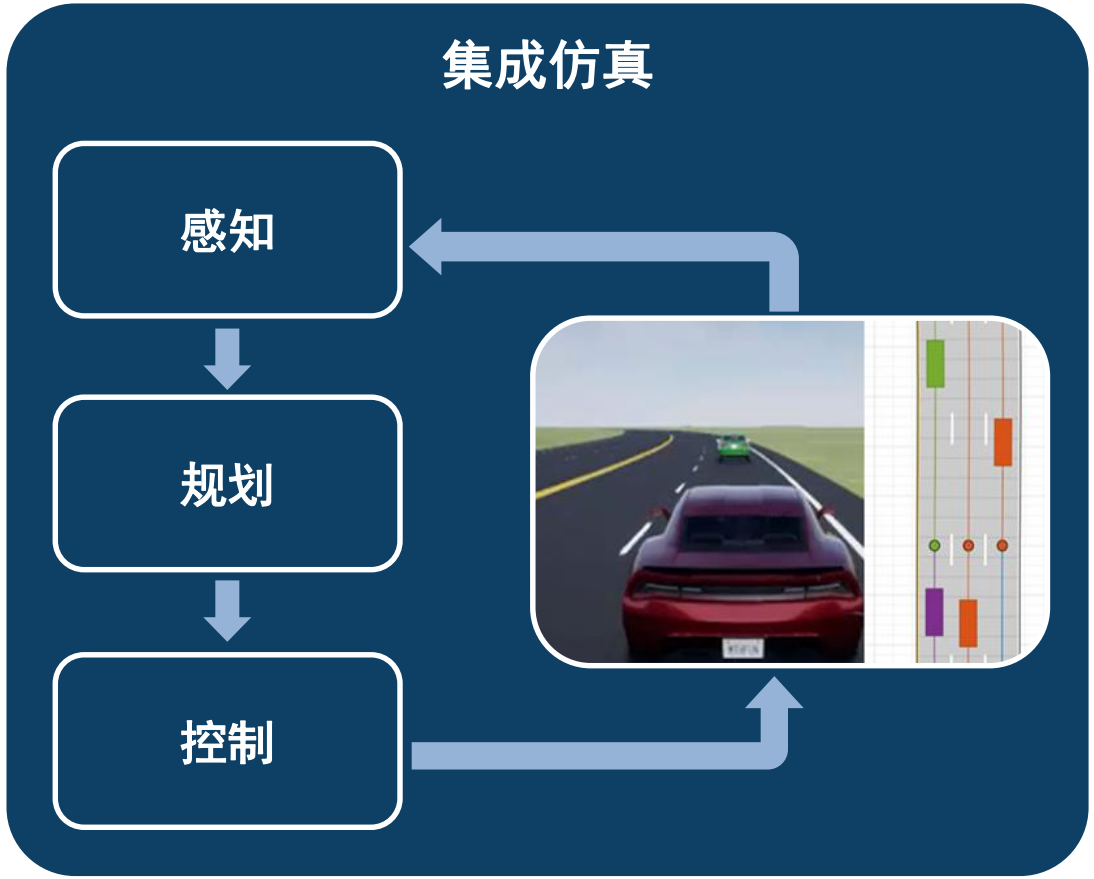


如何串联和加速多个专业的算法开发？



如何将其他资源集成到我们的仿真环境？

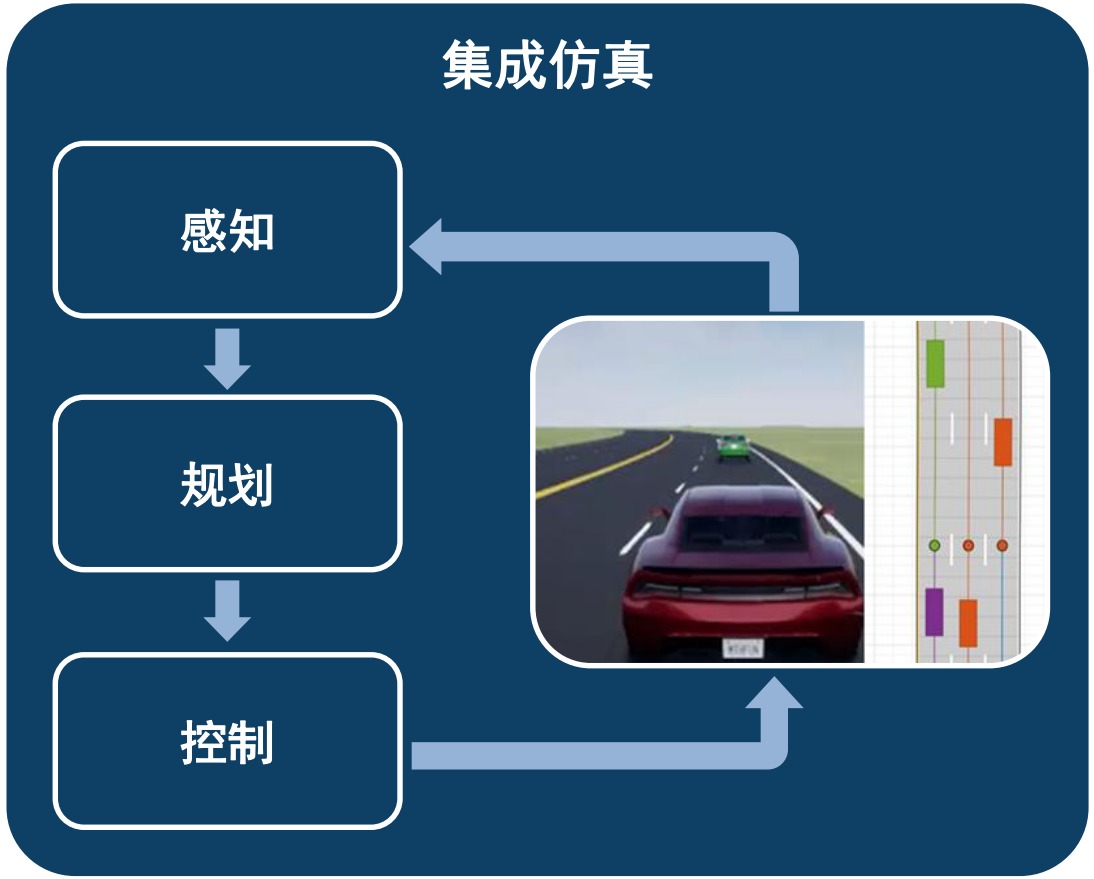
第一步：从帮助文档中已有的示例开始



Documentation All Examples

- Automated Driving Toolbox
  - 真值标注, 感知, 传感器融合, 路径规划, 传感器数据合成等
- Model Predictive Control Toolbox (分类: Automated Driving Applications)
  - 自适应巡航, 车道保持, 带间距控制的车道跟随等
- Simulink Test (分类: Systematic Testing and Reporting)
  - 测试带传感器融合的车道跟随控制器

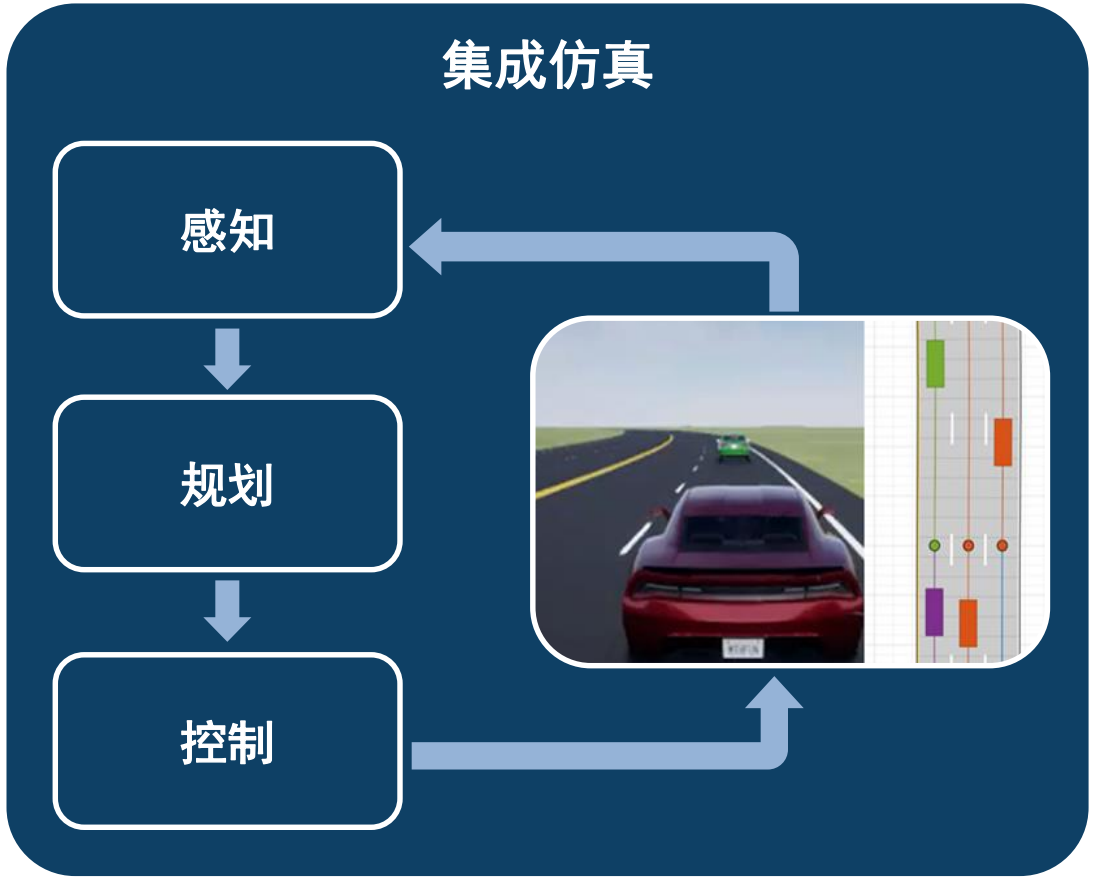
第二步：通过参加培训积累工具使用的经验



MATLAB and Simulink Training

- 使用 MATLAB 实现自动驾驶
- 使用 MATLAB 进行深度学习
- MATLAB 计算机视觉
- Simulink 系统和算法建模
- Simulink 代码集成
- 为 AUTOSAR 软件组件生成代码
- Simulink 模型测试和验证
- Polyspace Bug Finder for C/C++ 代码分析
- 按需定制培训课程 (联系我们)

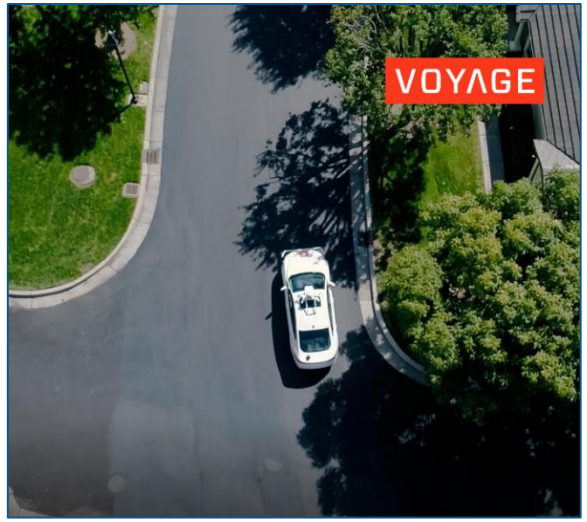
第三步：借助咨询服务推动实际项目的开展



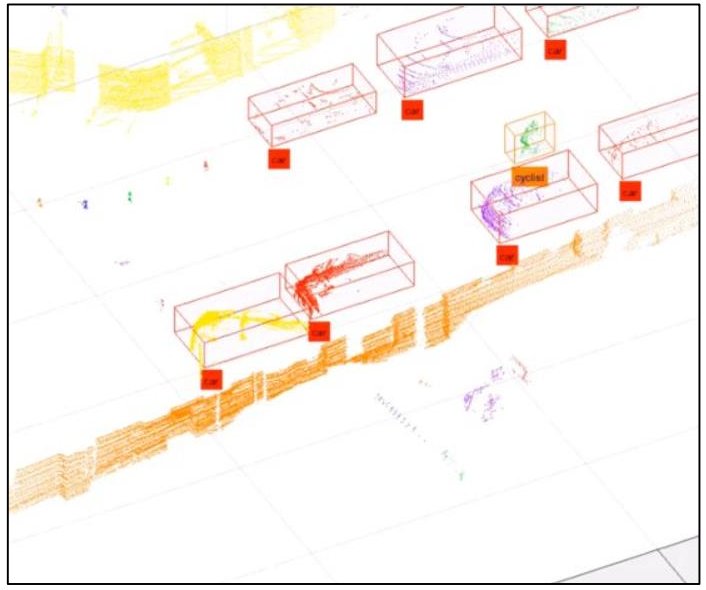
MATLAB and Simulink Consulting Services

- 图像处理与计算机视觉
- MATLAB 与 Hadoop 和 Spark
- 工具集成
- ISO 26262 流程的部署
- 基于模型设计流程的建设
- 基于模型设计流程的评估与成熟度框架
- 自动驾驶开发工具的扩展 (联系我们)

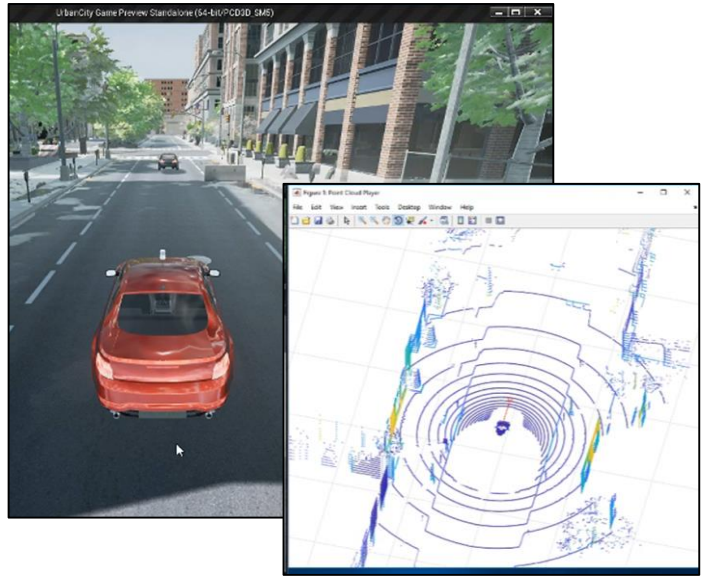
MathWorks帮助用户建立自动驾驶开发方式的成功案例



Voyage: MPC控制器的ROS集成

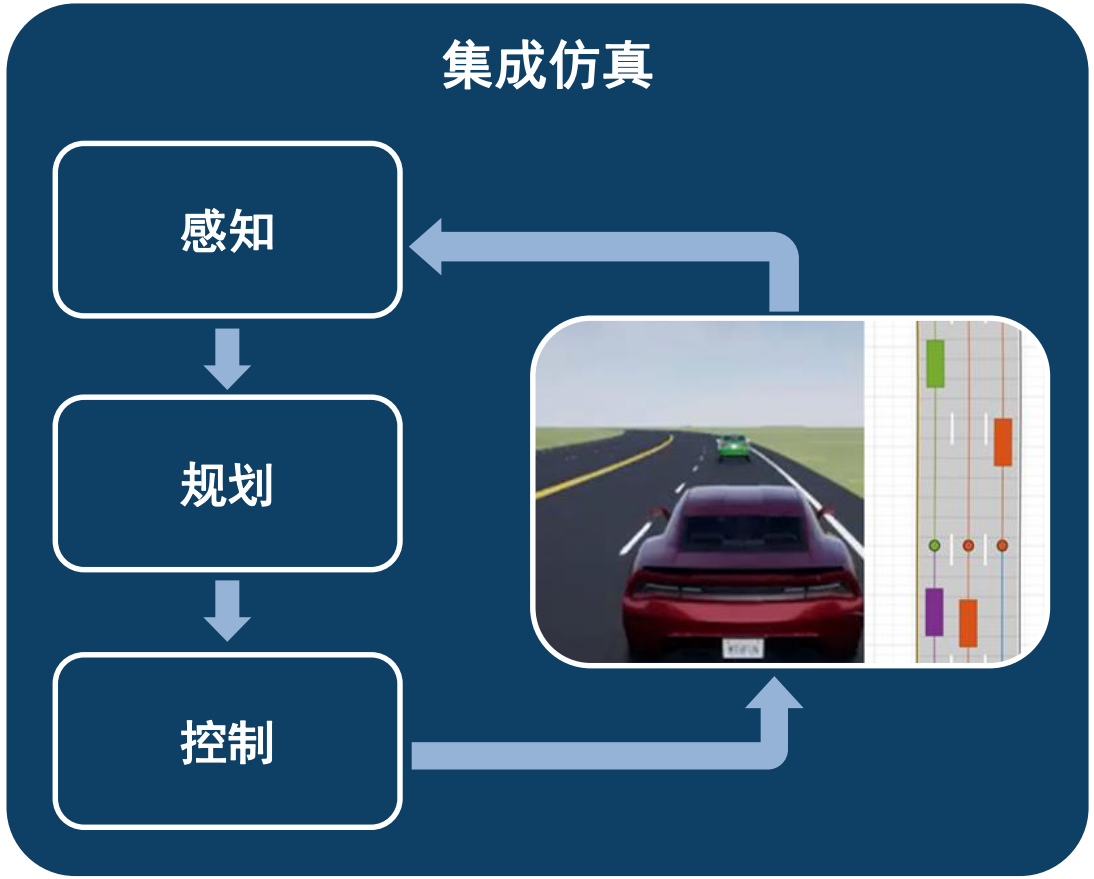


Autoliv: 激光雷达真值标注工具



Ford: 基于“虚幻”引擎的激光雷达模拟

准备好用MATLAB和Simulink开发自动驾驶系统



针对您的自动驾驶应用，MathWorks现场工程师可随时与您交流：

- 了解您的目标
- 推荐相关工具和方法
- 解答您的问题