What's New in MATLAB, Simulink, and RoadRunner for Automated Driving Development

Div Tiwari, MathWorks  
Linghui Zhang, MathWorks
Share the EXPO experience

#MATLABEXPO
Develop Automated Driving Applications with MATLAB, Simulink, & RoadRunner

Verify & Validate

Analyze Recorded Data

Design Virtual Worlds

Design Algorithms & Systems

Design Software

Integrate with External Tools and Software
Industry continues to invest in simulation for design & verification

- Maximize simulation value
- Increase automation
- Utilize interactive tools
- Ensure interoperability

- Analyze Recorded Data
- Design Virtual Worlds
- Design Algorithms & Systems
- Design Software
- Integrate with External Tools and Software

Verify & Validate
Design 3D scenes
Design 3D scenes

Design scenarios
Design 3D scenes

Design scenarios

Simulate driving applications
Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data
Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data
Design 3D scenes for automated driving applications with RoadRunner

RoadRunner Scene Builder

RoadRunner

RoadRunner Asset Library

OpenDRIVE

Filmbox

Third Party Simulators
- CARLA
- Unreal Engine®
- Unity®
- LGSVL
- VIRES Virtual Test Drive
- Metamoto
- IPG Carmaker
- Cognata
- Baidu Apollo
- Tesis Dynaware
- TaSS PreScan
- NVIDIA DRIVE Sim through Universal Scene Description (USD)

Here HD Live Map
TomTom HD Maps
Apollo HD Maps
Custom HD Maps

OpenDRIVE
OpenStreetMap
OpenCRG
Zenrin SD Maps

Geographic Information System (GIS) Files
- Point clouds
- Orthoimagery
- Vector data
- Elevation data

Custom Assets
Interactively design scenes with RoadRunner

- Author realistic roads and intersections
- Import/export OpenDRIVE
- Import HD maps
- Import Geographic Information System (GIS) files
- Export to common driving simulation environments

RoadRunner, RoadRunner Asset Library, RoadRunner Scene Builder
Learn about new features to author 3D scenes

- **Rumble Strips**
- **Traffic Island Tool**
- **OpenDRIVE 1.7**

**Road CRG Tool**
*RoadRunner*

**Traffic Island Tool**
*RoadRunner*

**Import and Export ASAM OpenDRIVE**
*RoadRunner*
Learn about new features to author 3D scenes

Scene Merge

RoadRunner API

Console Mode

Merge Multiple Scenes
RoadRunner

RoadRunner API
RoadRunner, Automated Driving Toolbox

Control RoadRunner
Programmatically Using Terminal
RoadRunner

R2022b
Updated
R2023a
R2022b
Build Custom 3D Scenes Using RoadRunner HD Map

- Import map and elevation data into MATLAB
- Upsample data and create RoadRunner HD Map
- Import into RoadRunner

Build Pikes Peak RoadRunner 3D Scene
Automated Driving Toolbox, Mapping Toolbox
Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data
Develop scenarios for automated driving applications with RoadRunner Scenario

- Trajectories
  - CSV
  - OpenSCENARIO 1.x

- Automate Tasks
  (import, export, set variables, …)
  - MATLAB*
  - C/C++
  - Python
  - Any gRPC supported
    language

- Trajectories and logic
  - OpenSCENARIO 1.x
  - OpenSCENARIO 2.0

- Simulate Actor Behaviors
  - MATLAB*
  - Simulink*
  - CARLA

* = Enabled through Automated Driving Toolbox
Interactively design scenarios with RoadRunner Scenario

- Add various vehicles and pedestrians
- Author trajectories
- Specify actions and logic
- Parameterize variations

**Scenario Edit Tool**
*RoadRunner Scenario*
Learn about new features to design scenarios

- Pedestrian Actors
- Actor Groups
- Reverse Motion

Character Assets
RoadRunner Scenario

Truck & Trailer Scenario
RoadRunner Scenario

Reverse Motion Along Lane
RoadRunner Scenario
Utilize prebuilt sample scenarios

- Cut in and brake
- Maintain space gap
- Free drive
- Lead collision
- User extensions

Open and Explore Sample Scenarios
RoadRunner Scenario
Export scenarios to OpenSCENARIO V1.x and V2.0

Export to ASAM OpenSCENARIO
RoadRunner Scenario

https://github.com/esmini/esmini
Simulate scenarios with actor behaviors in multiple simulators

**Simulate Actors with MATLAB and Simulink**
- Author MATLAB System objects or Simulink models to define actor behavior
- Tune parameters defined in MATLAB or Simulink
- Optionally, publish actor behavior as proto file or package

**Cosimulate Actors with CARLA**
- Associate CARLA behavior with vehicles
- Export scenes and visualizations to CARLA
- Run cosimulations with CARLA
Replay simulation from saved file

- Save simulation log to a file
- Replay from the file without computation from an associated cosimulation client
Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data
Simulate driving applications with Automated Driving Toolbox

- **Automated Driving Toolbox**
  - Application Examples
    - RoadRunner
    - RoadRunner Scenario
    - Vehicle Dynamics Blockset
    - Lidar Toolbox
    - Computer Vision Toolbox
    - Sensor Fusion & Tracking Toolbox
    - Navigation Toolbox
    - MPC Toolbox
  - Embedded Coder
  - GPU Coder
  - Simulink Test
  - Simulink Requirements
  - Simulink Real-Time

Use application example families as a basis for design and testing

Application Examples

- **Collision Avoidance**
- **Lane Following**
- **Lane Change**
- **Platooning**
- **Automated Parking**
- **Intersection Negotiation**
Simulate sensors for automated driving applications

Cuboid Sensors
- Radar IQ Signals
- Ultrasonic Detections

Cuboid & Unreal Engine
- Radar Detections
- Vision Detections
- Lane Detections
- Lidar

Unreal Engine Sensors
- Monocular Camera
- Semantic Segmentation
- Depth
- Fisheye Camera

Positional Sensors
- Wheel Encoder
- Global Positioning System (GPS)
- Inertial Measurement Unit (IMU)
- Inertial Navigation System (INS)

Commonly used tools: Automated Driving Toolbox™, Radar Toolbox, Navigation Toolbox™
Integrate Unreal Engine sensors with RoadRunner Scenario

- Co-simulate an autonomous emergency braking (AEB) system, designed in Simulink, with RoadRunner Scenario
- Uses a 14 degrees-of-freedom vehicle dynamics model
- Vision and radar sensors detect objects, and a terrain sensor detects road surface elevation in a 3D simulation environment
Design Platooning Controls with V2V Communication

- Leader follows behavior defined in RoadRunner Scenario
- Followers are modeled in Simulink
- Followers receive basic safety messages (BSM) and follow the leader
- Platooning controller specifies lateral and longitudinal controls for followers

Truck Platooning with RoadRunner Scenario
Automated Driving Toolbox, Simulink, Vehicle Dynamics Blockset
Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data

Scenario Builder for Automated Driving Toolbox

- Reconstruct Lanes
- Localize Ego Vehicle
- Reconstruct Targets
Build scenarios from recorded sensor data with Scenario Builder

Automated Driving Toolbox

Scenario Builder Support Package

- Camera images
- Lidar point clouds
- GPS
- IMU
- Map Data

- OpenSCENARIO v1.x
- CSV Trajectories

RoadRunner Scene Builder

RoadRunner Scenario

Lidar Toolbox

Computer Vision Toolbox

Deep Learning Toolbox

Sensor Fusion & Tracking Toolbox

Navigation Toolbox

Scenario Builder (Support Package)
Automated Driving Toolbox
Generate RoadRunner Scenario from Recorded Sensor Data

- Ego trajectories are extracted from GPS
- Non-Ego trajectories are extracted from Camera or Lidar
- RoadRunner API generates and runs scenario

**Scenario Builder for Automated Driving Toolbox, RoadRunner Scenario**
New examples demonstrate building scenarios from recorded data

Lane-level Ego Localization

Reconstruct Targets

Reconstruct Lanes

Ego Localization Using Lane Detections and HD Map
Scenario Builder for Automated Driving Toolbox, Navigation Toolbox

Fuse Recorded Lidar and Camera Data to Generate Vehicle Track List
Scenario Builder for Automated Driving Toolbox, Sensor Fusion and Tracking Toolbox

Generate Road Scene Using Lanes from Labeled Recorded Data
Scenario Builder for Automated Driving Toolbox, Lidar Toolbox, Computer Vision Toolbox
Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data

automated-driving@mathworks.com
Thank you