자율 주행 시스템을 위한 테스트 시나리오 개발

김종헌 부장, 매스웍스코리아
Develop Automated Driving Applications
with MATLAB, Simulink, & RoadRunner

Virtual Worlds
- Scenes
- Sensors
- Scenarios
- Dynamics

Algorithms
- Detection
- Localization
- Tracking
- Planning
- Decision & Controls

Software
- Code
  - C/C++
  - GPU HDL
- Architectures
  - AUTOSAR
  - ROS DDS

Development Platform
- Analyze
- Simulate
- Design
- Deploy
- Integrate
- Test
Develop **virtual worlds** for automated driving applications
Develop algorithms for automated driving applications

Surround Vehicle Sensor Fusion

Highway Lane Change Planner and Controller
Develop software for automated driving applications
Develop scenarios for automated driving applications

Set map-aware vehicle paths, scenario logic, conditions and goals

Highway Lane Change Planner with RoadRunner Scenario
Develop Scenarios for Automated Driving Applications with RoadRunner Scenario

- Design and Simulate Scenarios
- Interface with OpenSCENARIO
- Simulate with MATLAB, Simulink, and CARLA
Develop Scenarios for Automated Driving Applications with RoadRunner Scenario

Design and Simulate Scenarios

Interface with OpenSCENARIO

Simulate with MATLAB, Simulink, and CARLA
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

2020 자율 주행 세미나- RoadRunner를 이용한 자율 주행 시뮬레이션 3차원 Scene 모델링
Interactively design scenarios with RoadRunner Scenario

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

Scenario Edit Tool
RoadRunner Scenario
Simulate map-aware paths and scenario logic

Follow lanes when no path is specified

Speed actions

Lane change actions

Lateral offset actions
Design actor paths and trajectories

- Cubic interpolation
- Clothoid interpolation
- EuroNCAP (clothoid-arc-clothoid)

Route Timing Tool
RoadRunner Scenario
Programmatically vary scenario parameters

MATLAB, gRPC, and Command-line APIs
- Define scenario variables in editor
- Set variables programmatically from API

Programmatic Scenario Interfaces
RoadRunner Scenario
Programmatically vary scenario parameters

MATLAB, gRPC, and Command-line APIs
- Define scenario variables in editor
- Set variables programmatically from API
- Run simulations
- Export to OpenSCENARIO

Programmatic Scenario Interfaces
RoadRunner Scenario
Develop Scenarios for Automated Driving Applications with RoadRunner Scenario

Design and Simulate Scenarios
- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters

Interface with OpenSCENARIO

Simulate with MATLAB, Simulink, and CARLA
Export scenarios to OpenSCENARIO V1.x and V2.0

OpenSCENARIO V1.x

OpenSCENARIO V2.0

MathWorks is an ASAM Member and actively participates in the OpenSCENARIO 2.0 Implementers Forum

https://github.com/esmini/esmini

Export to ASAM OpenSCENARIO
RoadRunner Scenario
Import and edit trajectories from OpenSCENARIO V1.x

- Import trajectories from OpenSCENARIO V1.x
- Interactive edit trajectories
- Relocate trajectories in different scenes
- Extract the path for use with scenario logic

Import Trajectories from ASAM OpenSCENARIO Files
RoadRunner Scenario
Migrate trajectories from Driving Scenario Designer (DSD) to RoadRunner Scenario

Automated Driving Toolbox

- Design actor trajectories

RoadRunner Scenario

- Simulate scenario
- Import trajectories

Export trajectories

OpenSCENARIO 1.0
Develop Scenarios for Automated Driving Applications with RoadRunner Scenario

Design and Simulate Scenarios
- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters

Interface with OpenSCENARIO
- Export to OpenSCENARIO v2.0
- Export to OpenSCENARIO v1.x
- Import trajectories from OpenSCENARIO v1.0

Simulate with MATLAB, Simulink, and CARLA
Simulate scenarios with actor behaviors in multiple simulators

RoadRunner Scenario connects with actors in MATLAB, Simulink, and CARLA

Actors can read scenario states
- Action commands (path, speed, lane change, lateral offset)
- Pose and velocity of all actors in the scenario
- Dimensions of all actors
- Map lanes and lane boundaries

Actors write scenario states
- Their pose and velocity for each scenario simulation step
Design actor behaviors in MATLAB

Interface with RoadRunner scenario through MATLAB APIs with Automated Driving Toolbox

- Connect to scenario simulation
- Read world state from the scenario
- Read actor specific supervisory actions from scenario
- Write actor states to the scenario
- Report errors, warnings to the scenario

Simulate RoadRunner Scenarios with Actors Modeled in MATLAB

RoadRunner Scenario, Automated Driving Toolbox™
Simulate with speed action follower designed in MATLAB

- Design speed action follower behavior in MATLAB
- Associate MATLAB behavior with actor in RoadRunner Scenario
- Simulate and visualize results
Design actor behaviors in Simulink

Interface with RoadRunner Scenario using blocks from Automated Driving Toolbox

- **RoadRunner Scenario**
  - Establish a model’s interface with scenario

- **RoadRunner Scenario Reader**
  - Read the world state: Actor pose, velocity, color, supervisory actions

- **RoadRunner Scenario Writer**
  - Write an actor’s state to scenario
  - Report errors, warnings to scenario

Simulate RoadRunner Scenarios with Actors Modeled in Simulink

*RoadRunner Scenario, Automated Driving Toolbox™*
Simulate with trajectory follower designed in Simulink

- Explore built-in trajectory following behavior with linear velocity
- Design actor behavior in Simulink which includes controls and dynamics
- Simulate and compare results

**Trajectory Follower with RoadRunner Scenario**

RoadRunner Scenario, Automated Driving Toolbox™
Simulate with lane change planner designed in Simulink

- Design ego actor to implement planner
- Define trajectories and logic for target actors
- Visualize possible and selected ego trajectories

Highway Lane Change Planner with RoadRunner Scenario
RoadRunner Scenario, Automated Driving Toolbox™, Navigation Toolbox™
Simulate with actor behaviors designed in CARLA

### RoadRunner Scenario
- Design scene

### CARLA
- Build game
- Design CARLA actor
- Simulate actor

Cosimulate Actors with CARLA
RoadRunner Scenario
Develop Scenarios for Automated Driving Applications with RoadRunner Scenario

Design and Simulate Scenarios
- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters

Interface with OpenSCENARIO
- Export to OpenSCENARIO v2.0
- Export to OpenSCENARIO v1.x
- Import trajectories from OpenSCENARIO v1.0

Simulate with MATLAB, Simulink, and CARLA
- Author actor behaviors in MATLAB
- Author actor behaviors in Simulink
- Author actor behaviors in CARLA
Partner with MathWorks to extend scenario workflows

Extend verification workflows with MATLAB & Simulink

RoadRunner Scenario

Extend actor design workflows with MATLAB & Simulink

Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows
Partner with MathWorks to extend scenario workflows

Verification workflows:
- Generate scenarios from recorded data
- Generate scenario variations
- Automate testing scenarios

Actor design workflows:
- Integrate planning & controls
- Integrate sensors
- Integrate external code (C/C++, Python, ROS)

Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows.
Partner with MathWorks to extend workflows for tractor trailer

Engage with MathWorks engineers through proof-of-concept projects or Consulting Services to extend scenario workflows.
Develop Scenarios for Automated Driving Applications with RoadRunner Scenario

Design and Simulate Scenarios
- Design paths and scenario logic
- Relocate scenarios to different scenes
- Programmatically vary parameters

Interface with OpenSCENARIO
- Export to OpenSCENARIO v2.0
- Export to OpenSCENARIO v1.x
- Import trajectories from OpenSCENARIO v1.0

Simulate with MATLAB, Simulink, and CARLA
- Author actor behaviors in MATLAB
- Author actor behaviors in Simulink
- Author actor behaviors in CARLA
Thank you