



DSC 2023 EUROPE VR

Driving Simulation & Virtual Reality Conference & Exhibition

Elements of Practical Scenario Variation



Div Tiwari

Senior Product Manager, Automated Driving

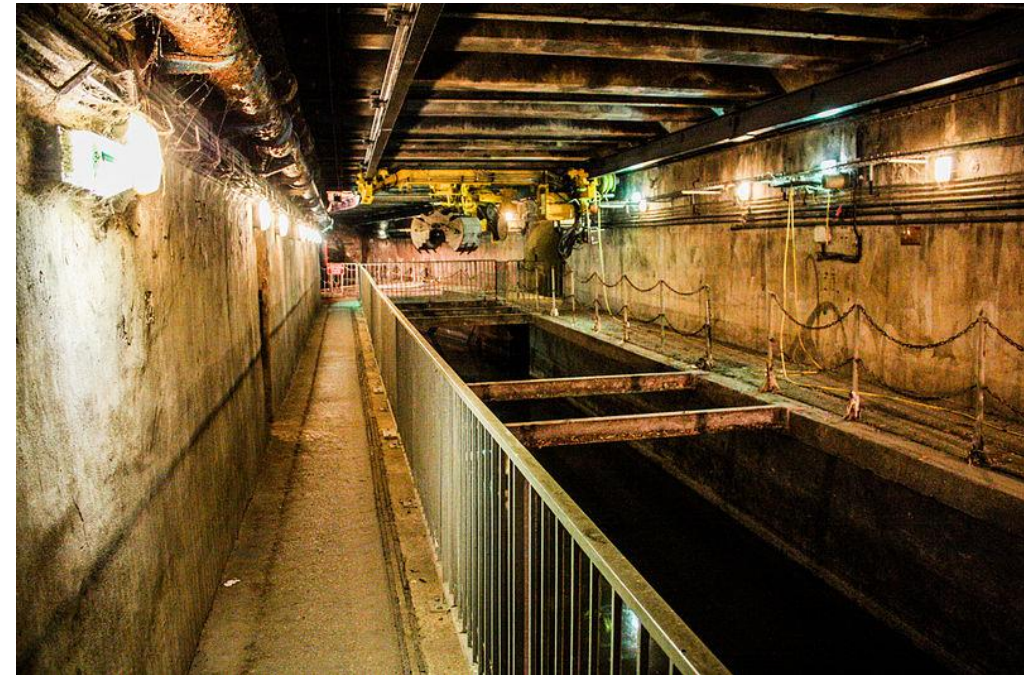
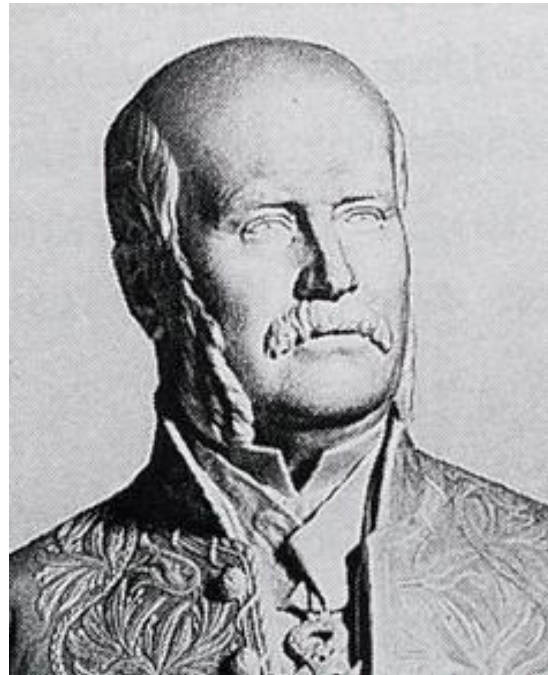
MathWorks

Antibes

September 6th – 8th 2023

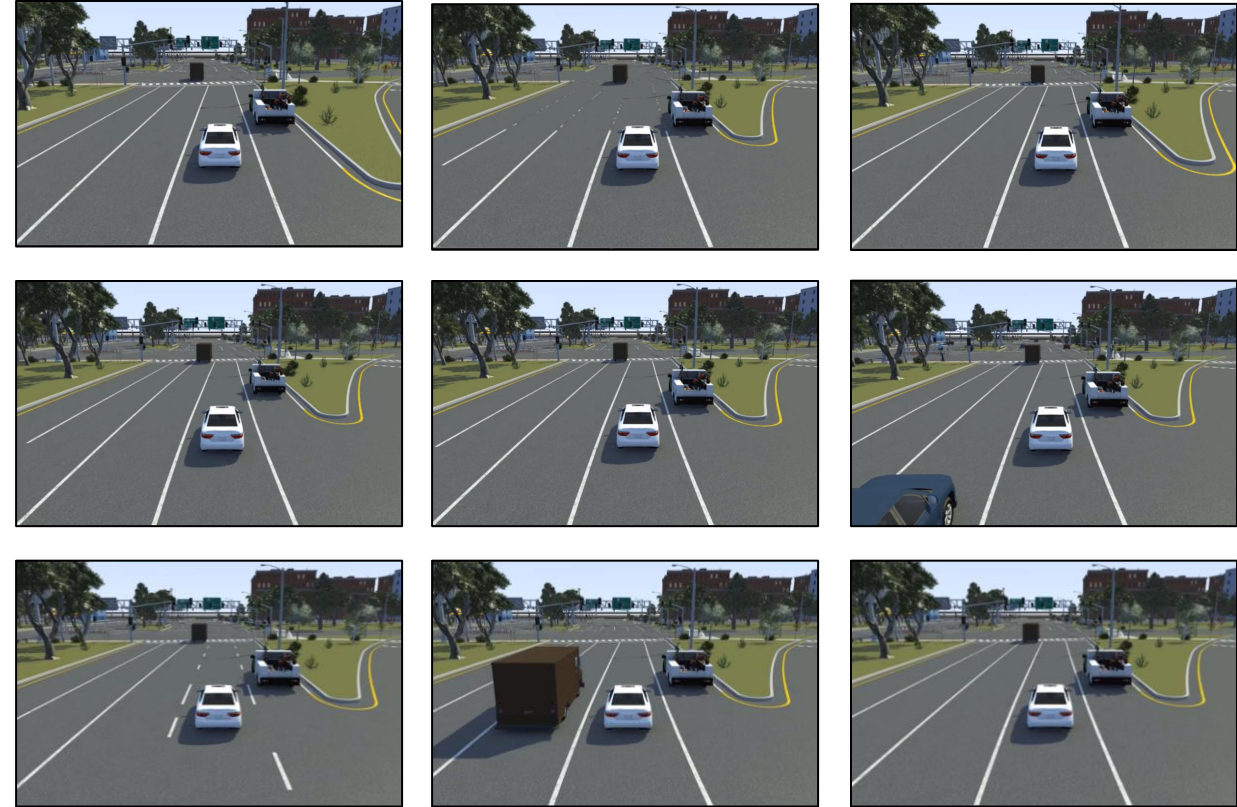
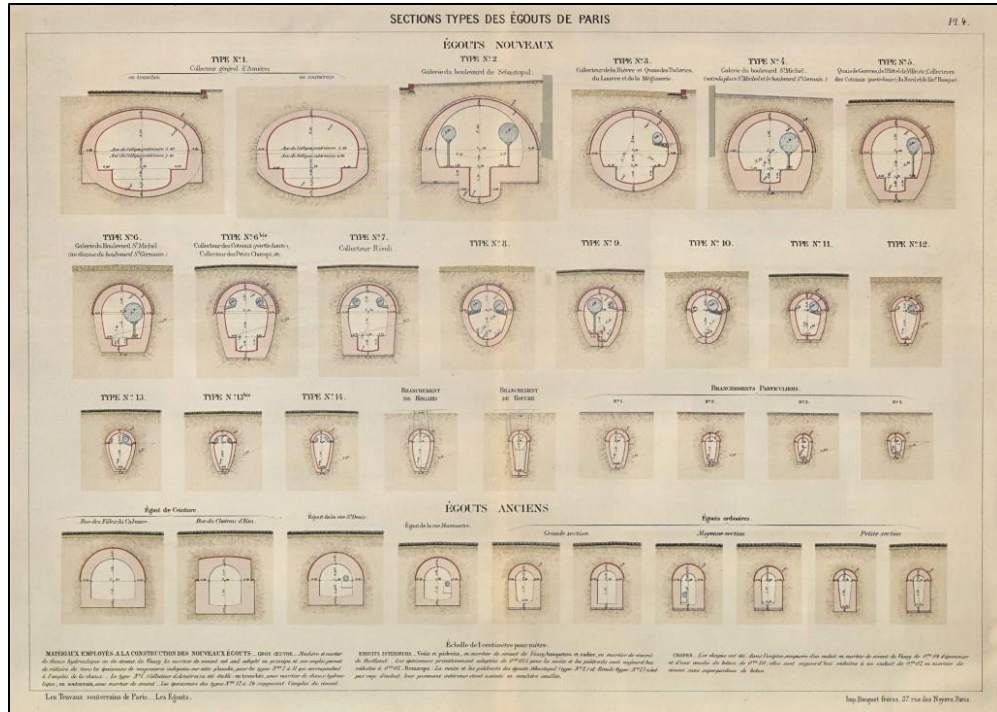


From: Juanedc, CC BY 2.0



Eugène Belgrand (1810-1878)

From Experiments to Simulation



Maximize **coverage** by testing representative scenarios that are highly varied.

The World is a Diverse Place



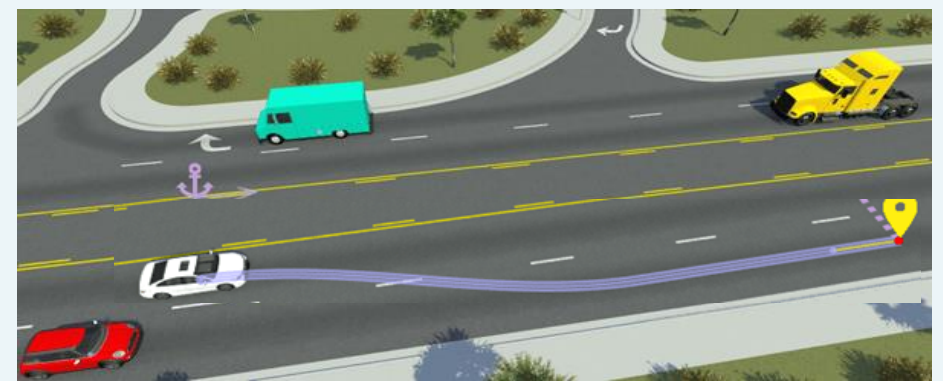
Roads, Lanes, and Markings



Geographic and Map data



Props and Signs



Actors – attributes and trajectories



RoadRunner Asset Library



RoadRunner Scene Builder



RoadRunner



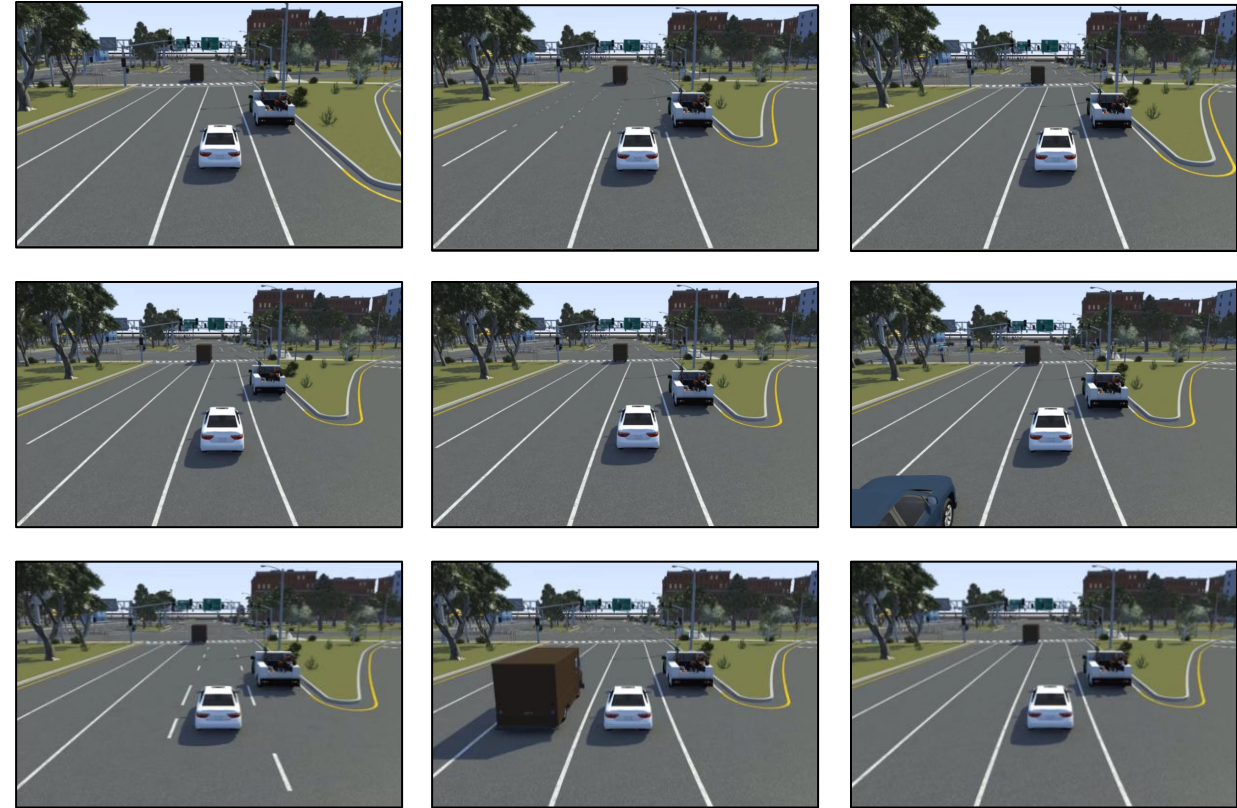
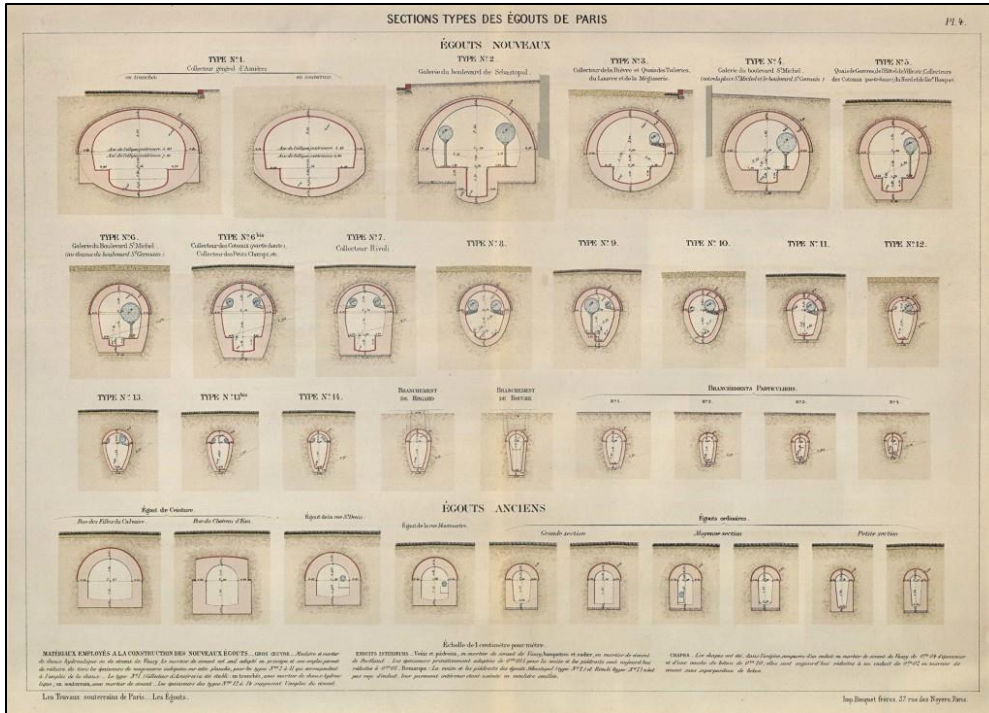
RoadRunner Scenario



3D model from: Hoang Vu, CC BY 4.0



From Experiments to Simulation



Maximize **coverage** by testing **representative** scenarios that are highly varied.

What are Scenario Variations?



Changes to actions, positions, speed



Changes to roads and lanes

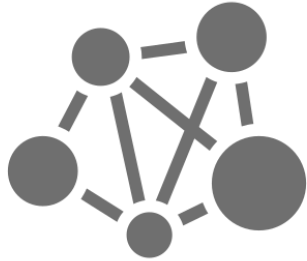


Changes to props and traffic



What is needed to maximize the value gained from generating driving scenario variations?

Elements of Practical Scenario Variation



Interoperability



Interactivity



Automation

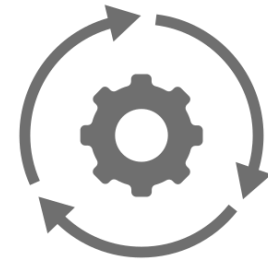
Elements of Practical Scenario Variation



Interoperability



Interactivity



Automation

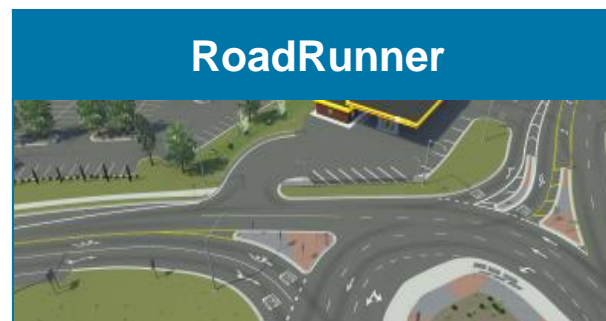
Interoperability – use best fit tools for your workflow

- Why it matters

In a challenging domain with varying needs, it allows you to leverage strengths of many tools and facilitates collaboration.

- Contemporary approaches

Support for ASAM OpenX[®] standards.



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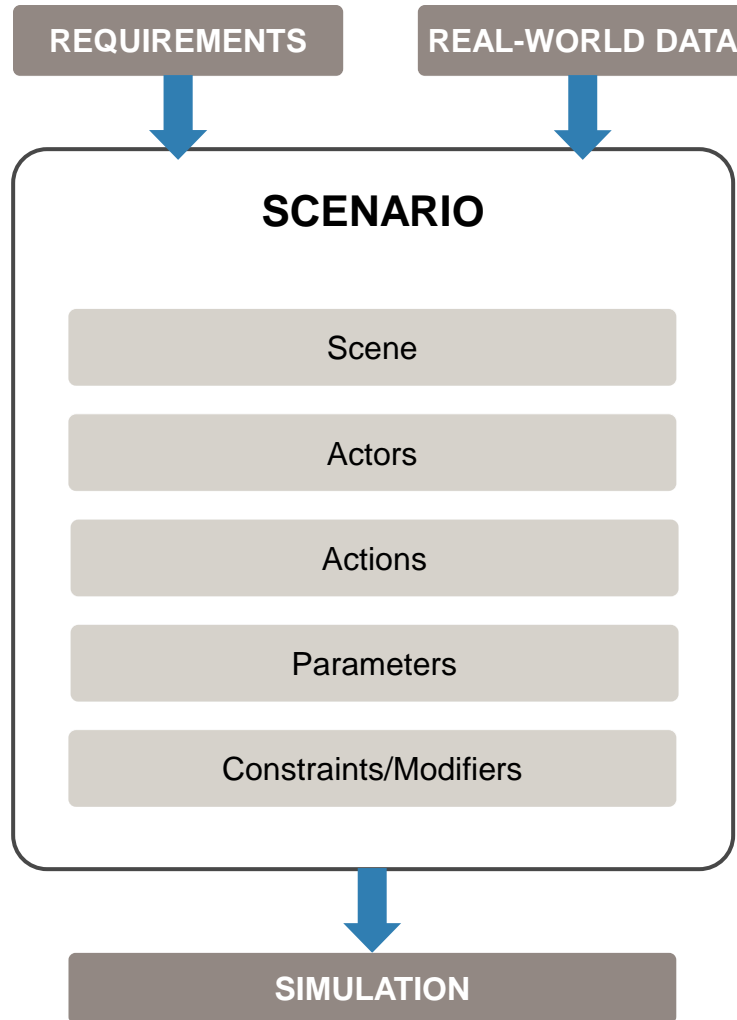
OpenDRIVE



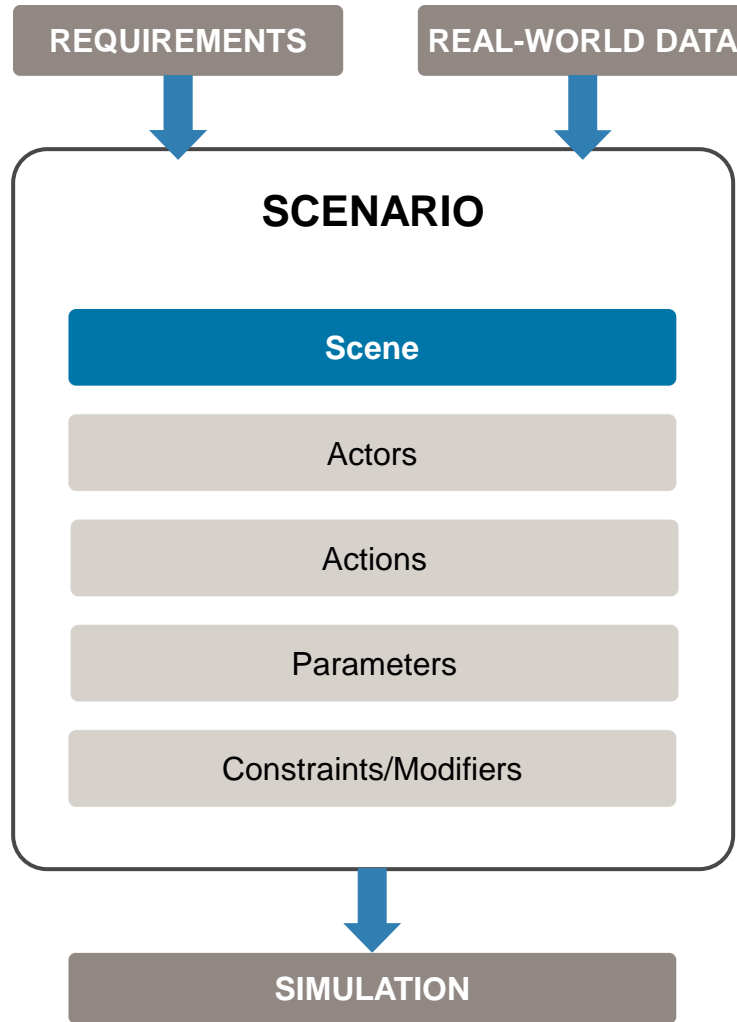
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OpenSCENARIO

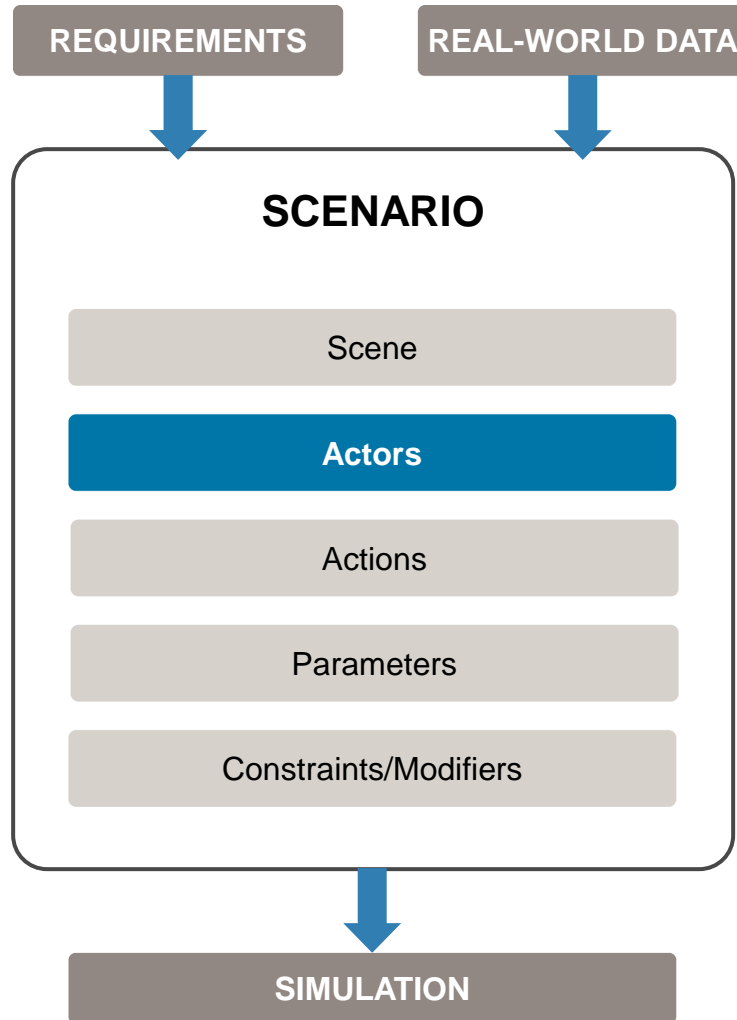
What makes a scenario?



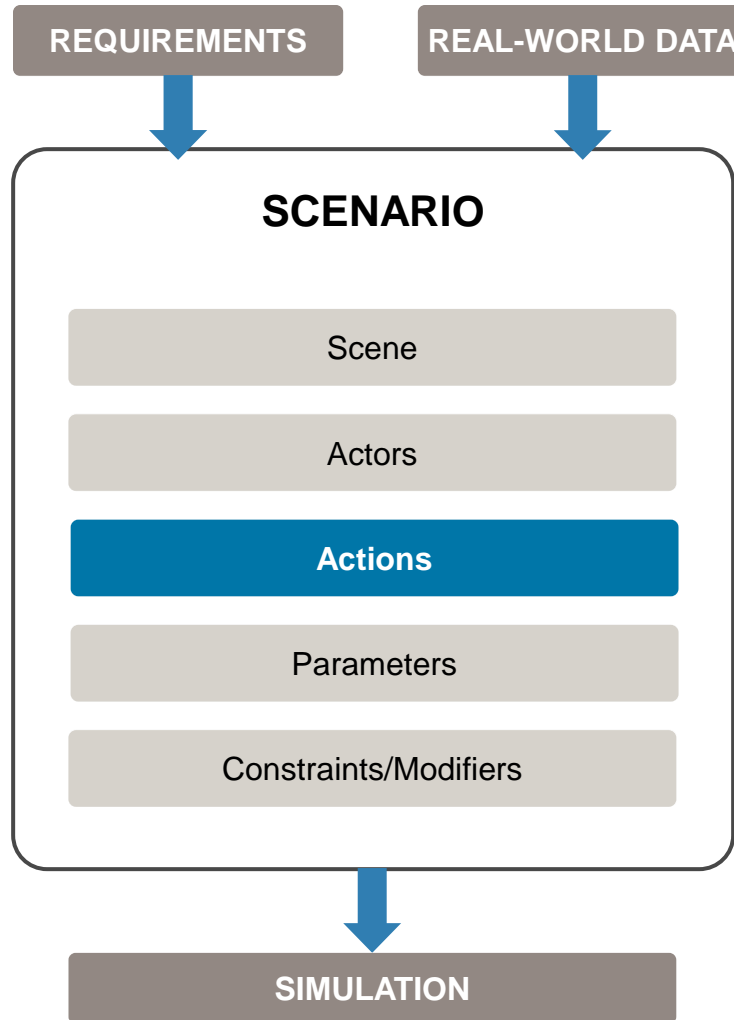
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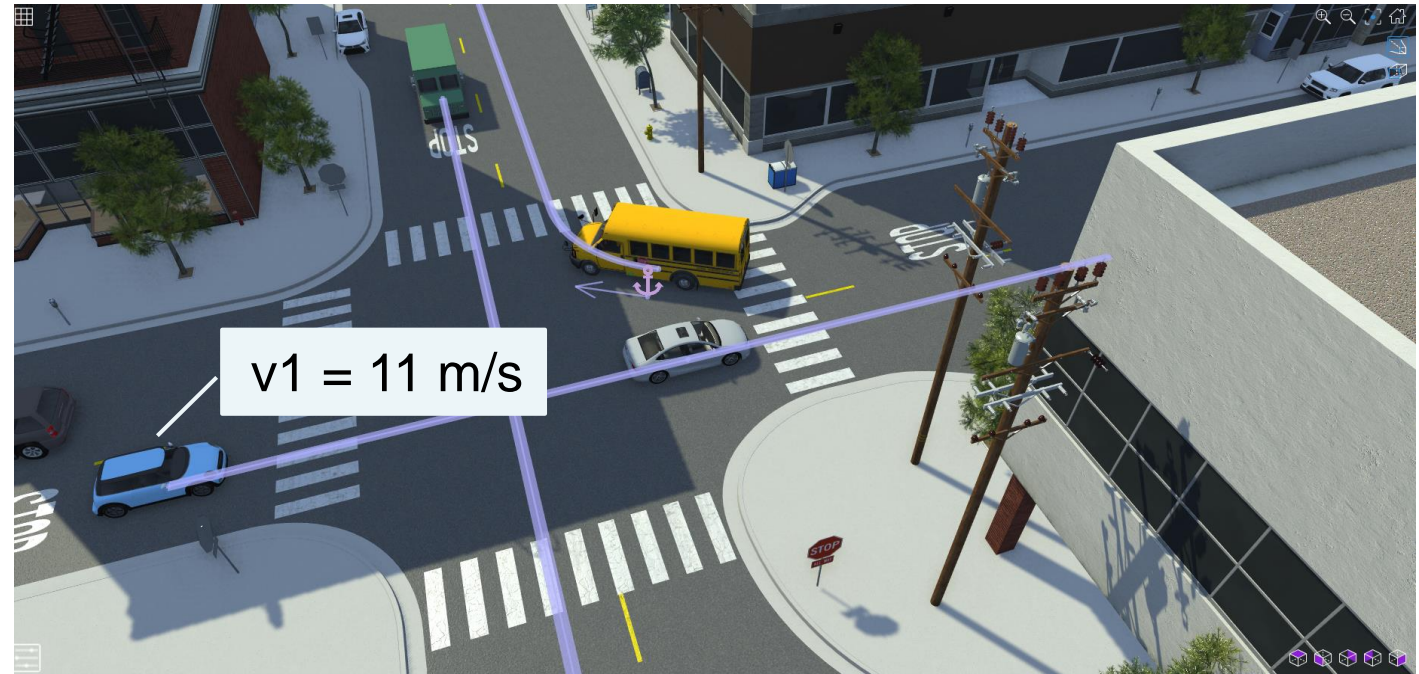
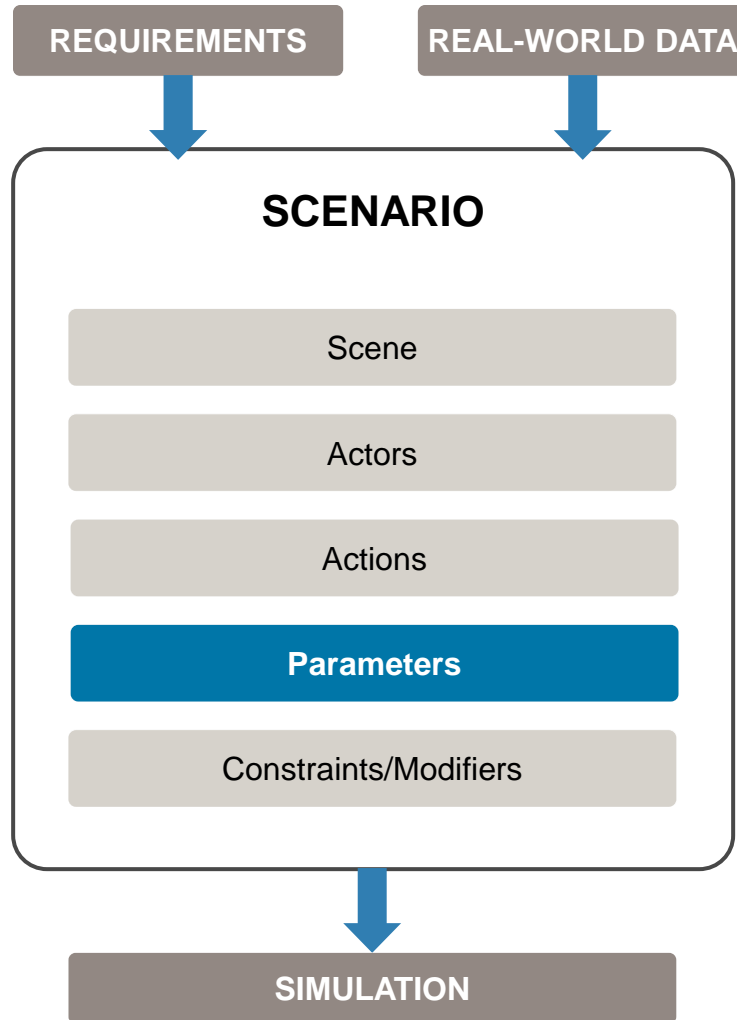
What makes a scenario?



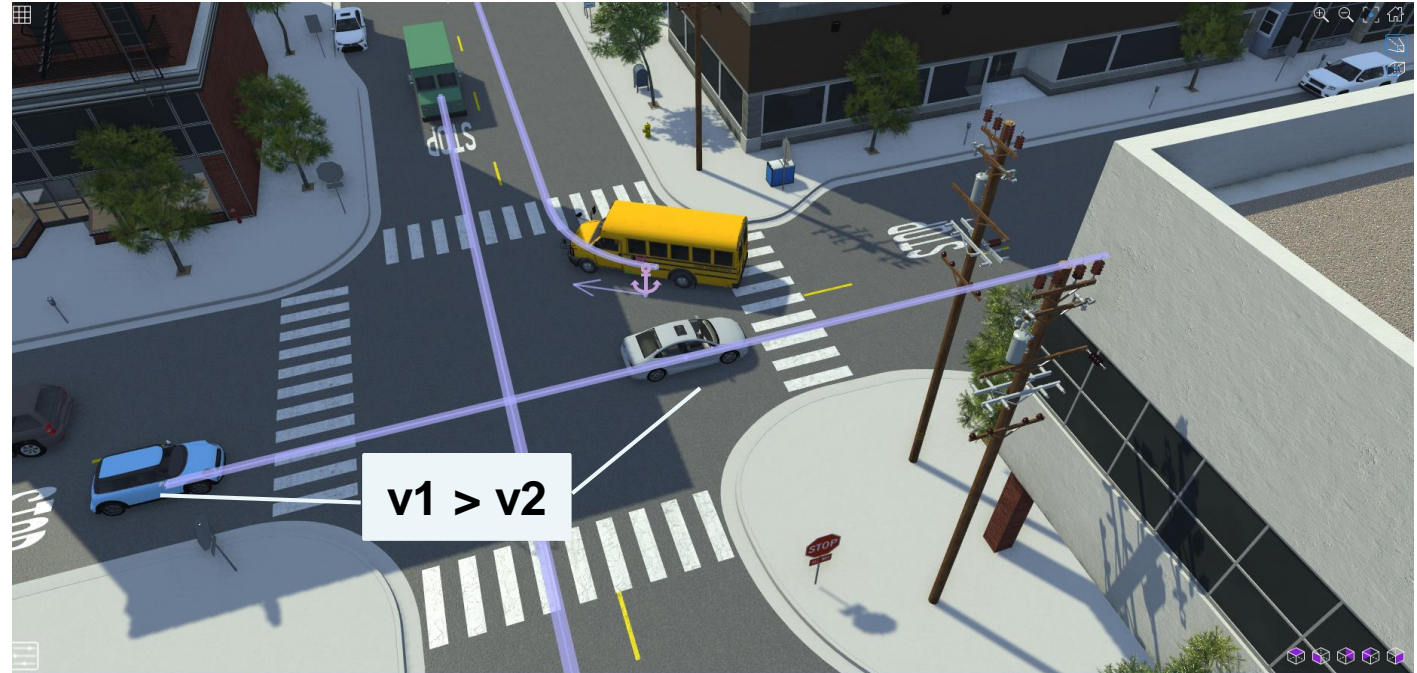
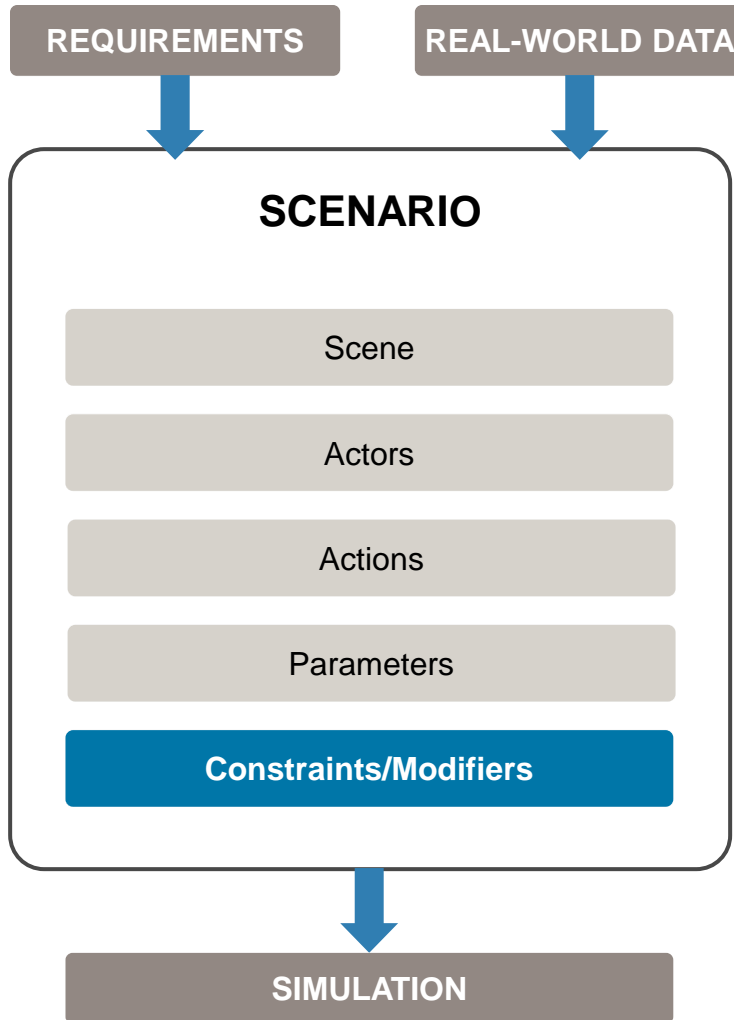
What makes a scenario?



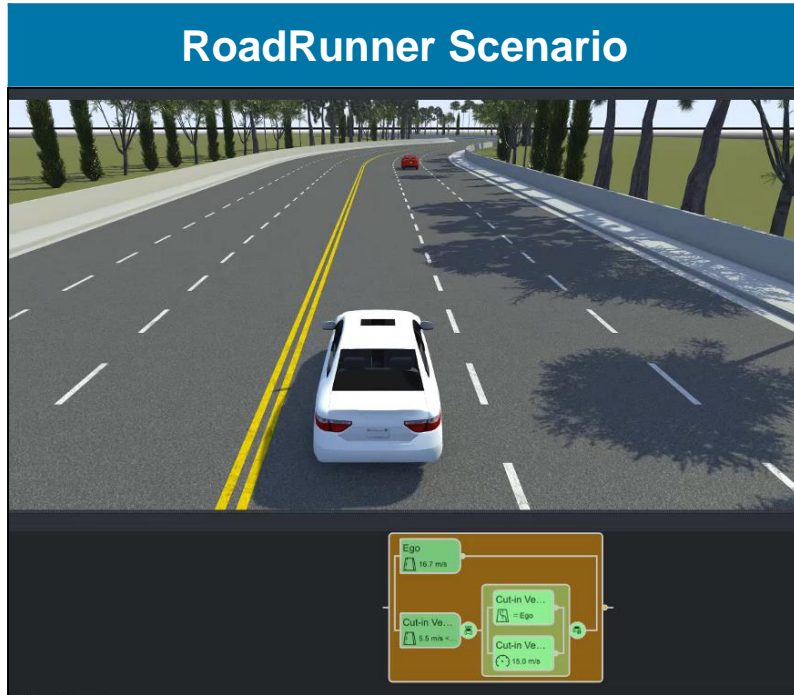
What makes a scenario?



What makes a scenario?



Interoperability - export scenarios to OpenSCENARIO V1.x and V2.0



OpenSCENARIO V1.x

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```



<https://github.com/esmini/esmini>

OpenSCENARIO V2.0

```

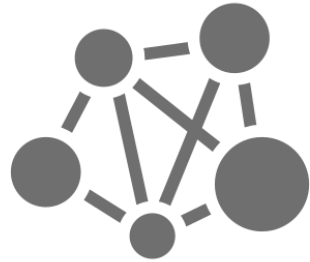
81 do parallel:
82   ego.drive() with:
83     along(sedan__route)
84     speed(16.66mps, at: start)
85   serial:
86     cut-in_vehicle.drive() with:
87       along(sedan2__route)
88       speed(5.5mps, slow)
89       until (cut-in_v
90   parallel:
91     cut-in_vehicle.
92     cut-in_vehicle.
93       speed(15mps,
94   with:
95     until (ego.time
96

```

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

[Export to ASAM OpenSCENARIO RoadRunner Scenario](#)

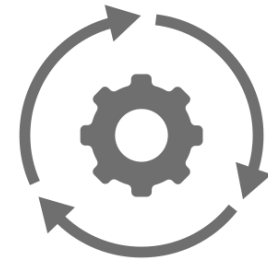
Elements of Practical Scenario Variation



Interoperability



Interactivity



Automation

Interactivity – representative scenes from geographic data



[Import Scene Data](#)

RoadRunner

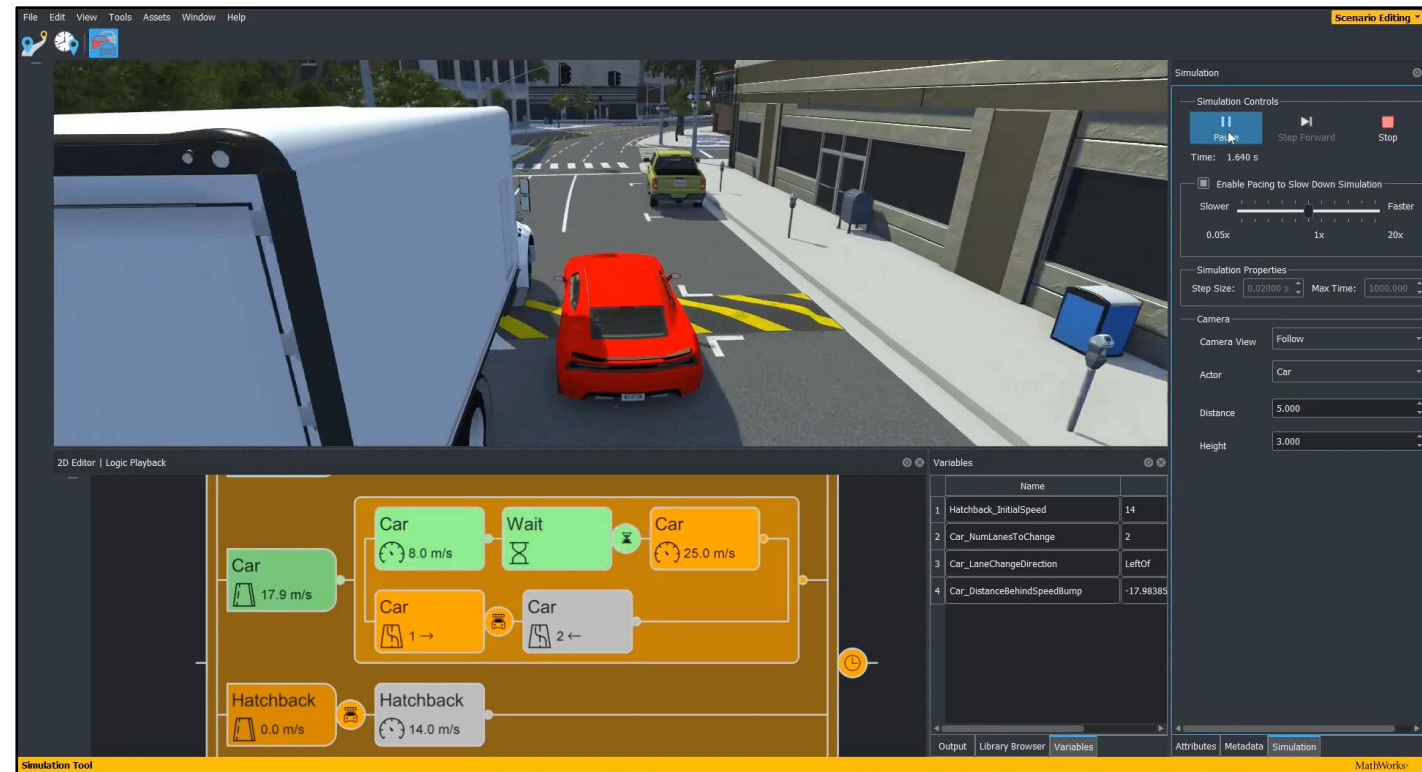
Interactivity – minimize ‘zero-to-simulation’ time

- *Why it matters*

Leverage humans’ intuitive understanding of real-world driving to design new scenarios or modify existing ones.

- *Contemporary approaches*

Interactive UI to define and modify the various components of a scenario.



[Scenario Edit Tool](#)

RoadRunner Scenario

Interactivity – understand what actors are doing and why

- *Why it matters*

Analyze actor behavior and make informed decisions for improvement.

- *Contemporary approaches*

Visualize scenarios with run-time annotations.

The screenshot displays the MathWorks Simulation Tool interface. The top portion shows a 3D simulation of a road scene with a white truck, a red car, and a yellow car. The bottom portion shows a logic editor with a flowchart and a variables table.

Simulation Controls:

- Pause (P)
- Step Forward
- Stop
- Time: 1.640 s
- Enable Pacing to Slow Down Simulation
- Slower (0.05x) to Faster (20x) slider

Simulation Properties:

- Step Size: 0.02000 s
- Max Time: 1000.000

Camera:

- Camera View: Follow

Actor:

- Distance: 5.000
- Height: 3.000

Variables Table:

Name	Value
Hatchback_InitialSpeed	14
Car_NumLanesToChange	2
Car_LaneChangeDirection	LeftOf
Car_DistanceBehindSpeedBump	-17.98385

Logic Editor:

The logic editor shows a flowchart with the following elements:

- Car (17.9 m/s) → Car (8.0 m/s) → Wait → Car (25.0 m/s)
- Car (1 →) → Car (2 ←)
- Hatchback (0.0 m/s) → Hatchback (14.0 m/s)

[Define Scenario Logic](#)

RoadRunner Scenario

Interactivity – understand what actors are doing and why

- *Why it matters*

Analyze actor behavior and make informed decisions for improvement.

- *Contemporary approaches*

Visualize scenarios with run-time annotations.

Provide quantitative metrics to evaluate system performance.

	M...	T...	R...	R...	F...	S...
1	0.0	-20	56	-4	1.0	1.0
2	0.0	-11	56	-5	1.0	1.0

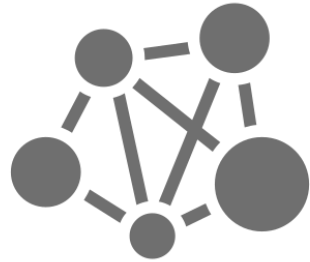
Ego Accel	0.00 m/s ²
Ego Curvature	0.01
Ego YawRate	0.06 deg/s
Current Set Speed	10.00 m/s
Current Ego Lane	2
Goal Lane	2
Lead Car Speed	NA
Headway to lead car	NA
Lead Car TTC	NA

TimeResolution	0.1 sec
ReplanRate	1 sec
TimeHorizon	2.3 sec
PreferredLane	2
SetSpeed	10 m/s
EgoFrmExt	5 m
TargetFrmExt	5 m
FrontSafetyGap	40 m
RearSafetyGap	10 m
egoLaneTTC	4 sec
nextLaneTTC	4 sec
LatDevWeight	1
TimeWeight	-1
SpeedWeight	1
MaxAccel	5 m/s ²
MaxCurvature	1
MaxYawRate	80 rad/sec
MinVelocity	0 m/s
Behaviors Enabled	CC.LCF.LC

Mode	Time	Long Dist	Long Velocity	Lat Dist	Max Accel	Max Kapa	Max YawRate	Cost	Valid	Ev
1	CC	3.0000	NaN	10.0000	0.0000	0.0032	0.0096	0.0962	-3.0000	1.0000
2	CC	2.0000	NaN	10.0000	0.0000	0.0032	0.0096	0.0962	-2.0000	1.0000
3	LC	3.0000	NaN	10.0000	3.5038	0.4136	0.0290	0.2913	0.1534	1.0000
4	LC	2.0000	NaN	10.0000	3.5038	1.1711	0.0557	0.5610	1.1534	1.0000
5	LCF	3.0000	NaN	4.9958	0.0000	2.5022	0.0098	0.0969	2.0042	1.0000
6	LCF	2.0000	NaN	4.9958	0.0000	3.7533	0.0101	0.0994	3.0042	1.0000

[Highway Lane Change Planner with RoadRunner Scenario](#)

Elements of Practical Scenario Variation



Interoperability



Interactivity

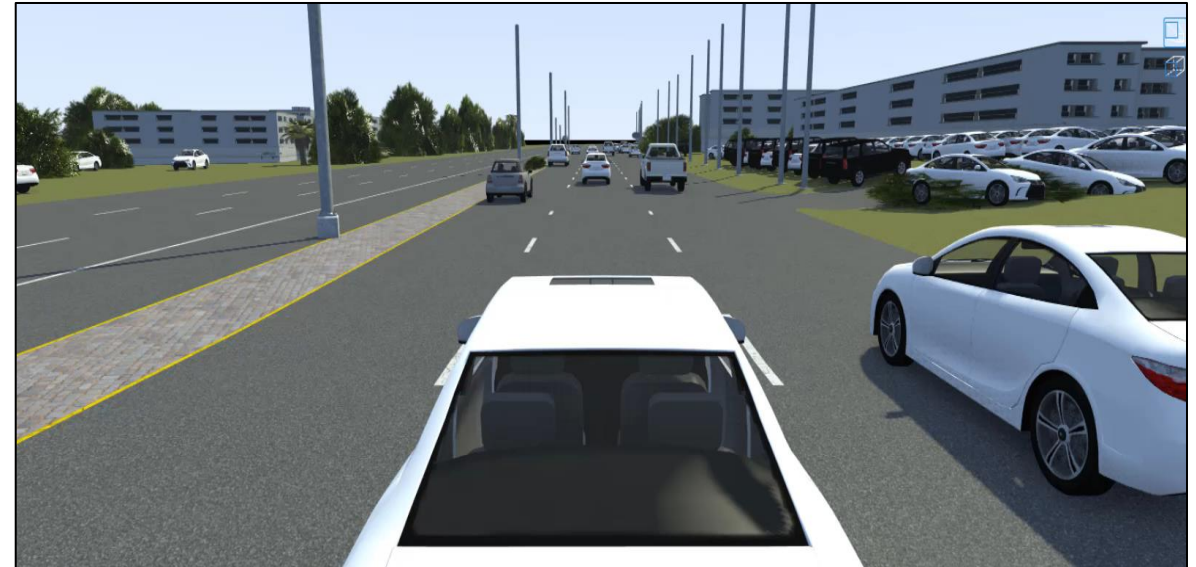


Automation

Automation – representative scenes from HD Map data

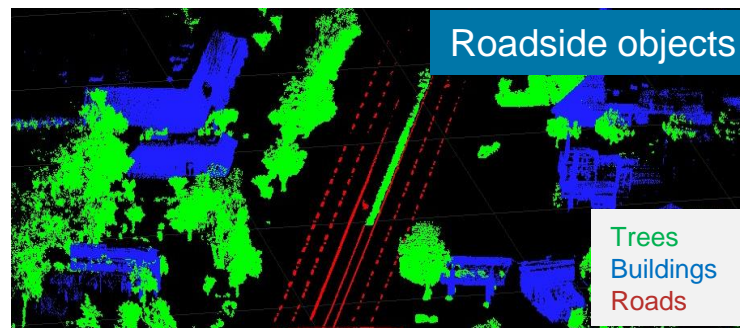
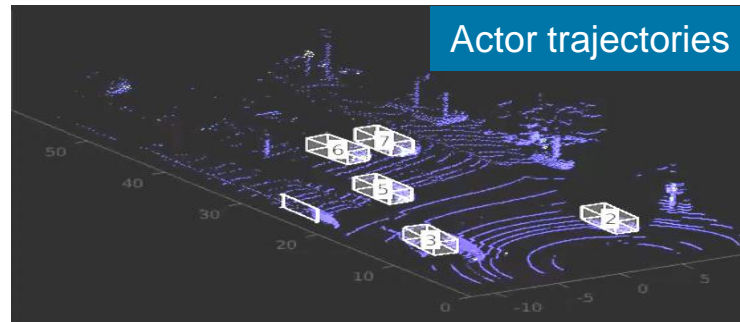
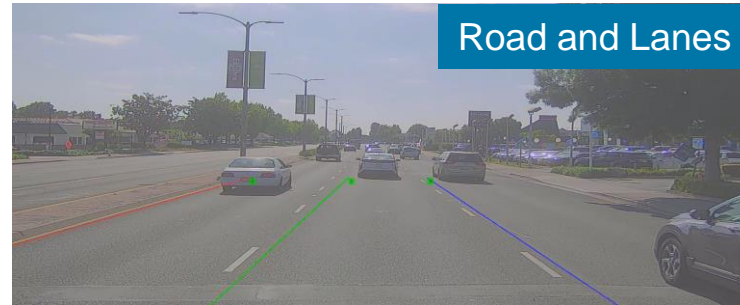


Automation – representative actors from real-world sensor data



Automation – representative actors from real-world sensor data

Automated Workflow



Using recorded sensor data:



Lidar



Camera



IMU



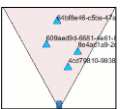
Radar



GPS



Lanes



Object List

[Scenario Builder](#)

Add-on to Automated Driving Toolbox

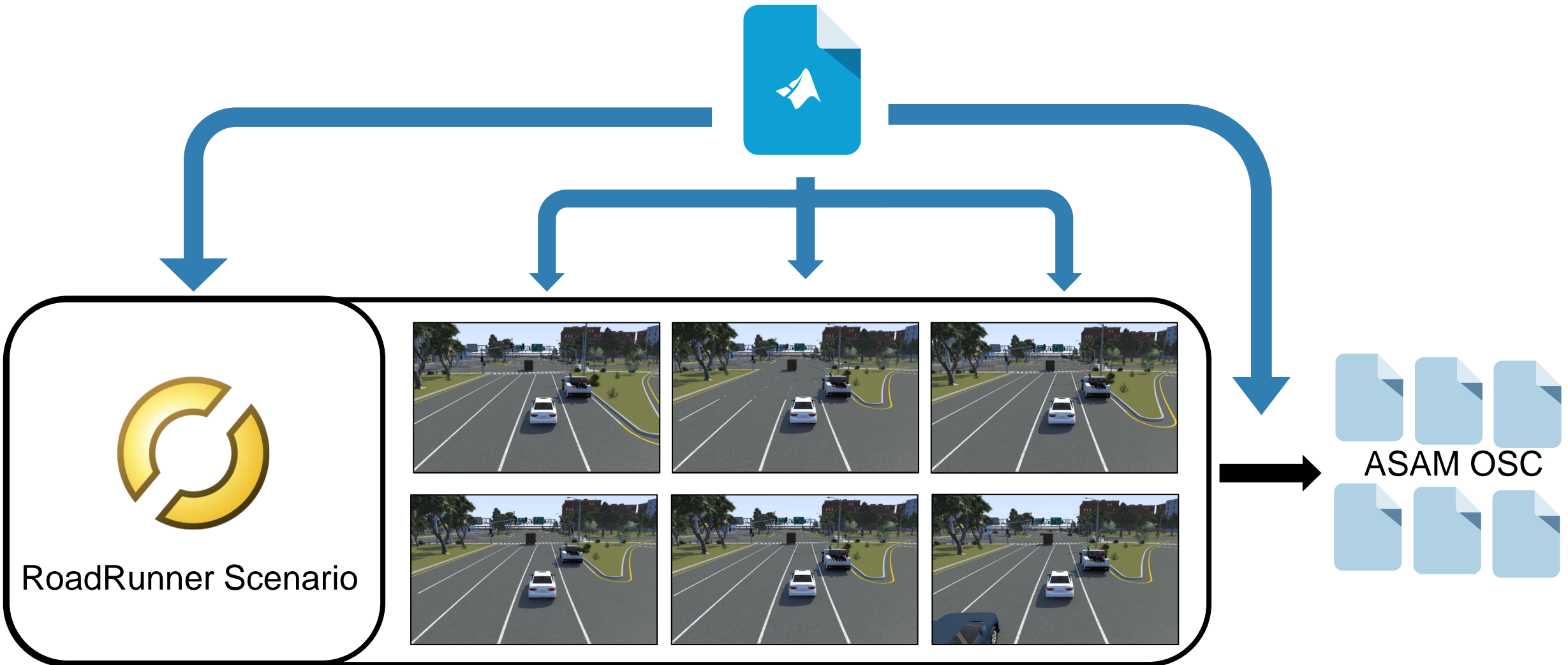
Automation – reuse actors in other scenes



[Relocate Scenarios](#)

RoadRunner Scenario

Automation – programmatic workflow and authoring



* Some programmatic variations shown are not available in a public release of RoadRunner Scenario

Automation

- *Why it matters*

Accelerate scenario generation to allow faster and more comprehensive testing.

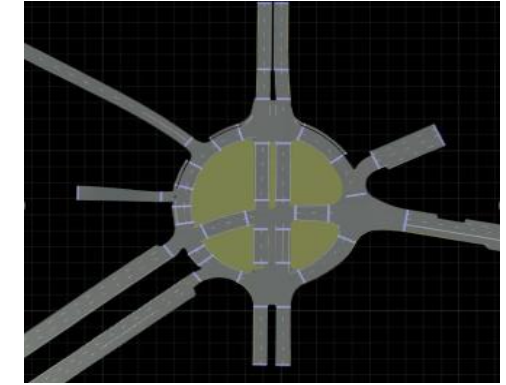
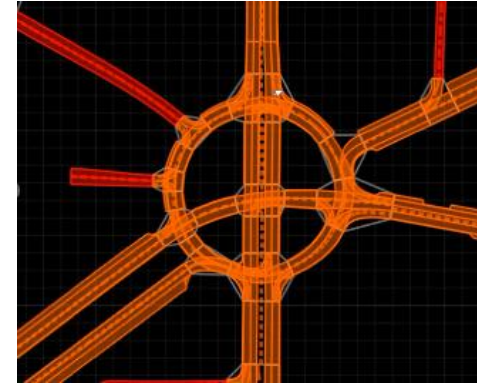
- *Contemporary approaches*

Scene generation from HD Map data

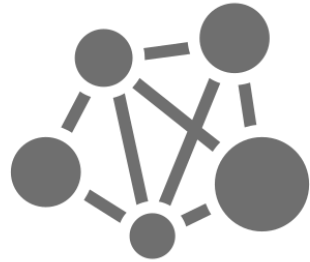
Scenario generation from sensor data

Scenario reuse across scenes

Programmatic APIs



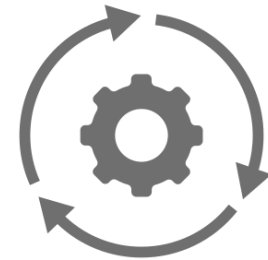
Elements of Practical Scenario Variation



Interoperability

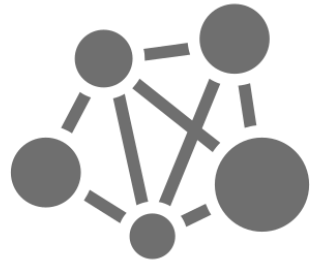


Interactivity



Automation

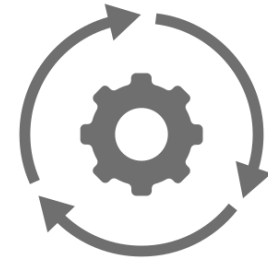
Continue the Conversation on Driving Scenarios



Interoperability



Interactivity



Automation

Meet us at exhibitor booth 15!

Or email: automated-driving@mathworks.com