





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



Rolandid-test-Alad Rolantal-2007-







Design 3D scenes

Design scenarios

Simulate driving applications

Build scenarios from recorded data





Interactively design scenarios with RoadRunner Scenario

- Add various vehicles and pedestrians
- Author trajectories
- Specify actions and logic
- Parameterize variations
- Spawn and Despawn vehicles as needed





Scenario Edit Tool RoadRunner Scenario



Build scenarios from recorded sensor data with Scenario Builder





Analysis, Extraction and Localization of static and dynamic objects



Virtual scenarios mimicking real-word sensor data

Scenario Builder for Automated Driving Toolbox Support package shipping with Automated Driving Toolbox from R2022b release



Scenario Builder - workflow

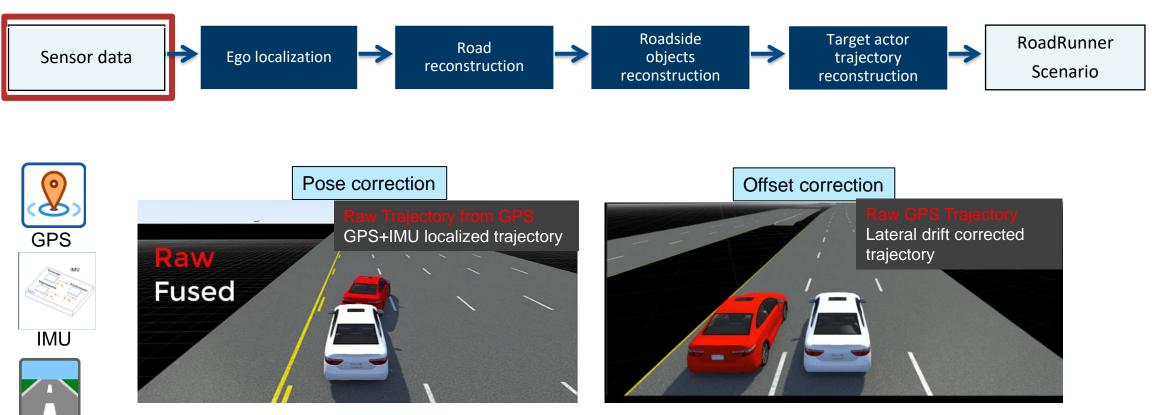








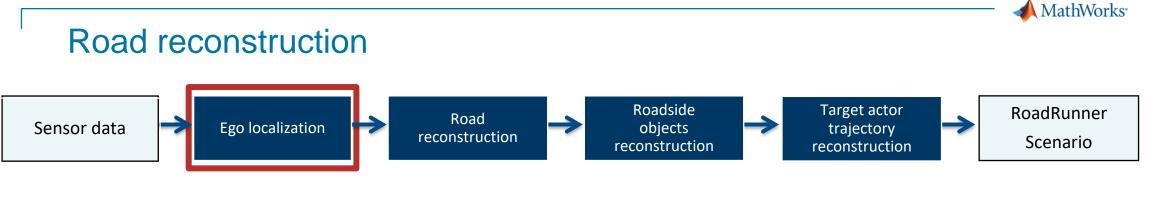
Scenario Builder - workflow

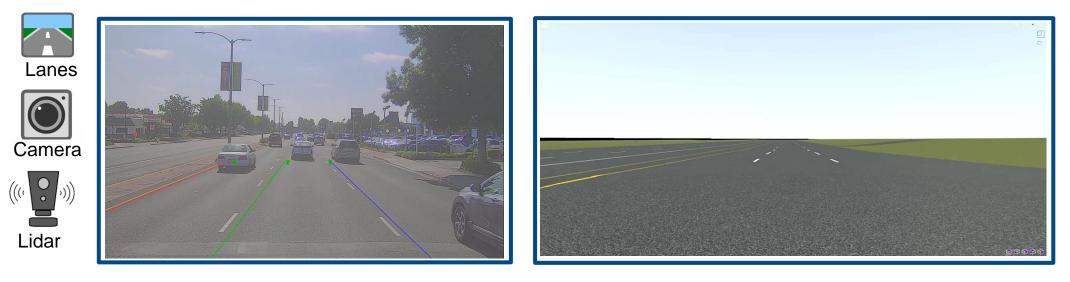


Correct position and orientation of ego actor using GPS and IMU fusion

Correct single/multi-lane level offsets using GPS, lane information and HD maps

- Lanes
- **P** HD Map

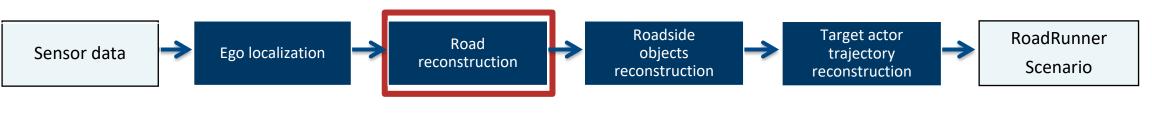




- Extract lanes, road boundaries from camera and lidar data
- Reconstruct road with lane add/drop, road curvature and junctions



Roadside objects reconstruction

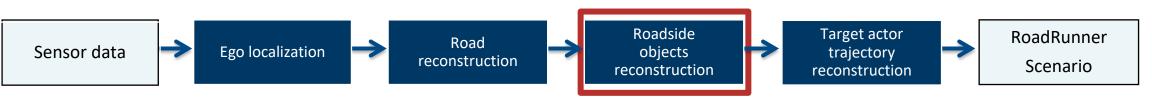




- Labelled Lidar data is used to reconstruct trees, buildings and other roadside objects.
 - Labels supported: buildings, trees, bushes, traffic cones, pylons, barricades, and electric poles
- Automate assets (trees and buildings) labelling using pre-trained models
- Alternatively use Camera + GPS to get approximate scene with roadside objects.



Trajectory reconstruction











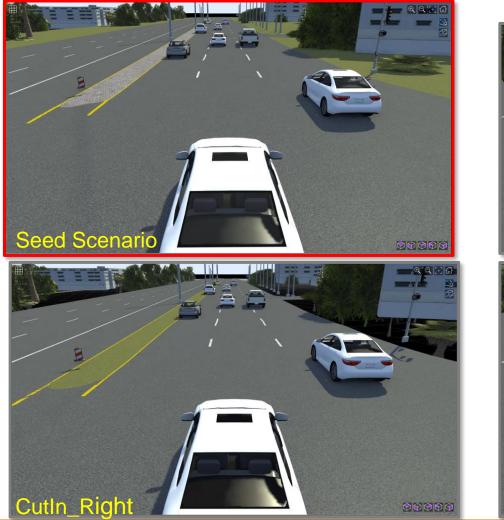


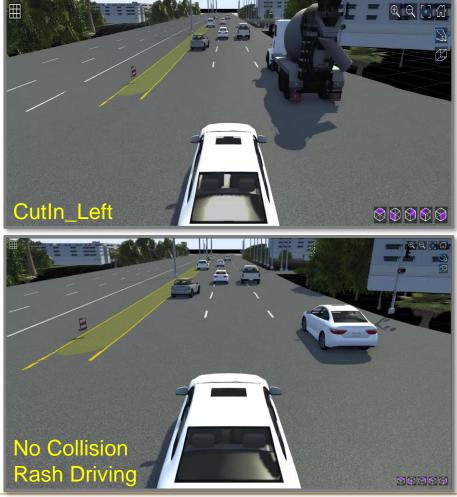


- Reconstruct dynamic actor tracklists, vehicles from camera or lidar or radar data and its combinations
- Lidar sensor data can enable extraction of objects from all the sides of the ego vehicle whereas Radar sensor data can enable farther objects.
- Camera sensor data can help identify object classes (car, truck etc.)



Variant scenarios

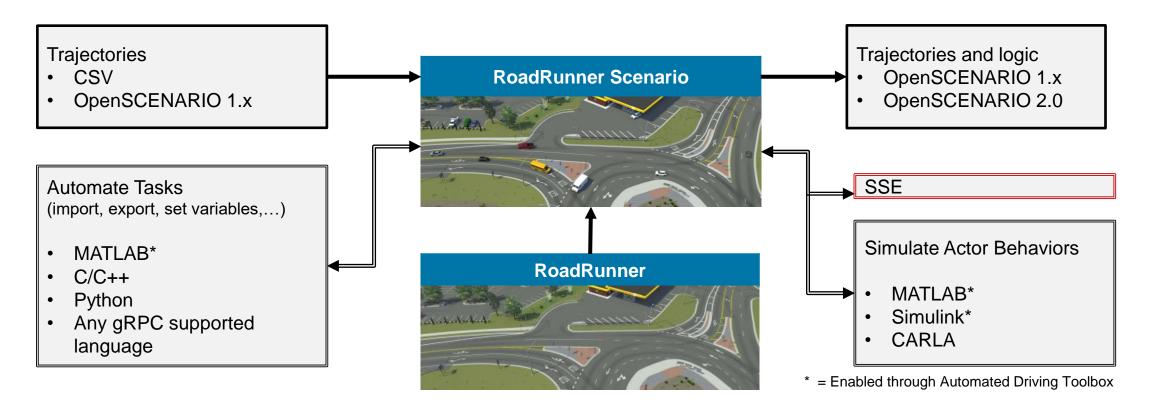




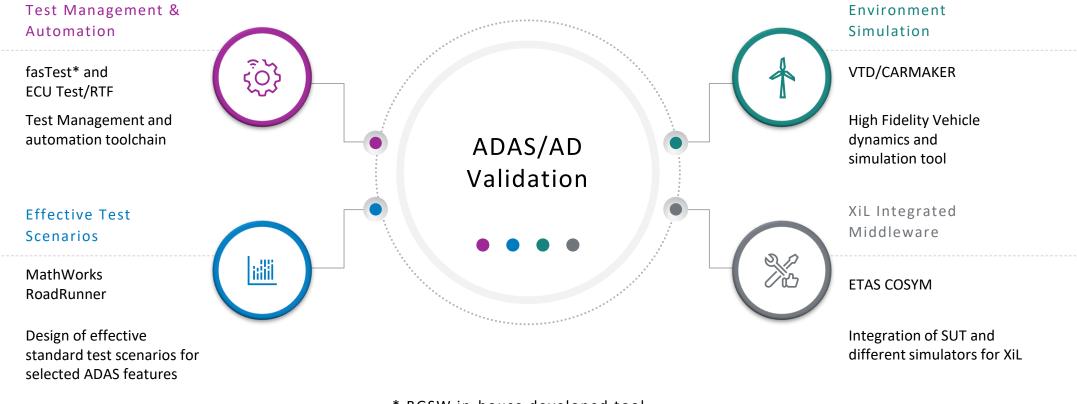




Develop scenarios for automated driving applications with RoadRunner Scenario



Co-Simulation framework: RoadRunner and Carmaker XiL integrated toolchain for ADAS V&V at BGSW:



* BGSW in-house developed tool

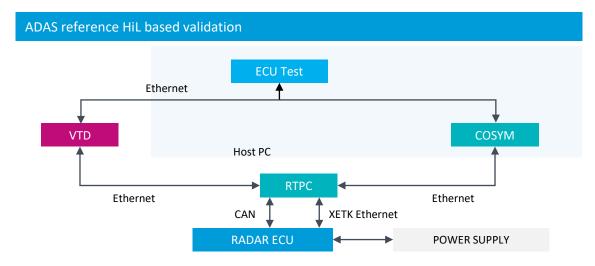


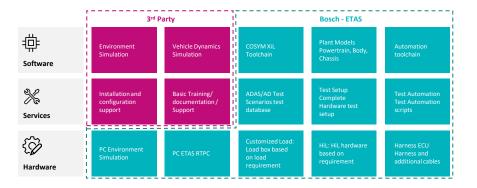
Co-Simulation framework: RoadRunner and Carmaker ADAS reference implementation – XiL based

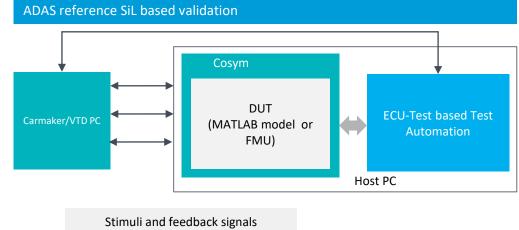
Development of XiL based hybrid ADAS validation environment with integration of

- Environment simulation tools (VTD, CarMaker, etc.)
- Co-simulation tools (like COSYM, Model connect, Silver, etc.)
- Test automation tools (like ECU test, Robot framework, etc.)
- MCD tools (like INCA, CANOE, CanAlyzer, etc.)

Development of database for scenario-based test cases for ADAS functions with scenarios





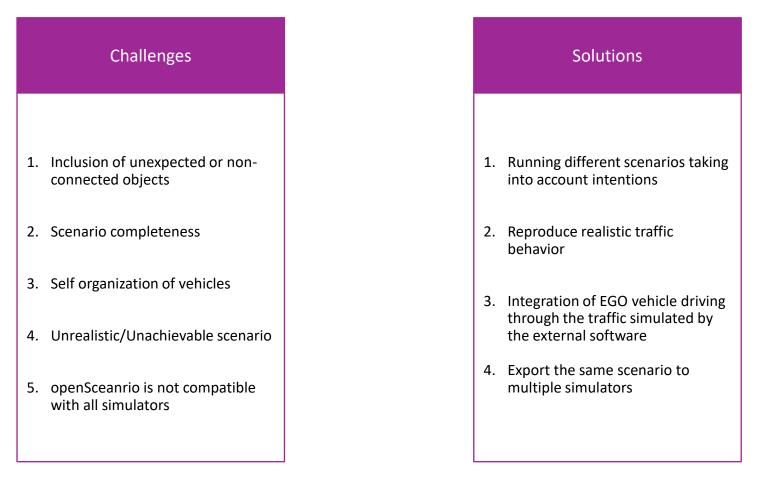


15 Confidential | BGSW : SDS V&V team | 01-09-2022

© Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.

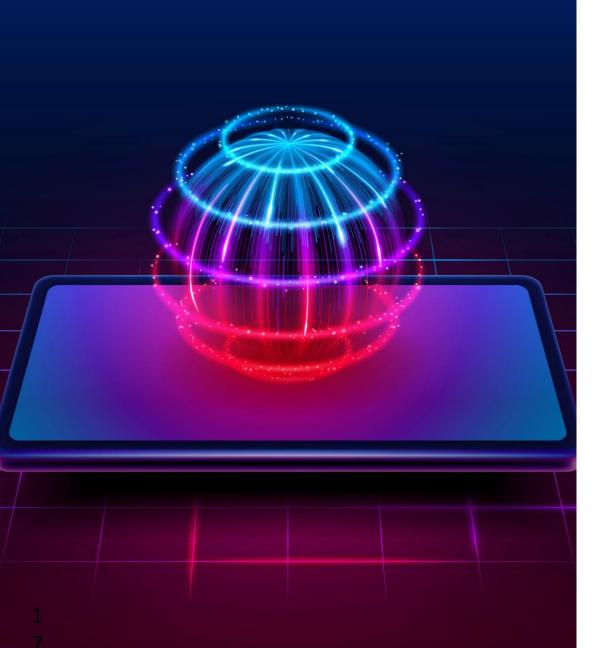
BOSCH

Co-Simulation framework: RoadRunner and Carmaker Why Co-simulation?



16 Confidential | BGSW : SDS V&V team | 01-09-2022 © Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.



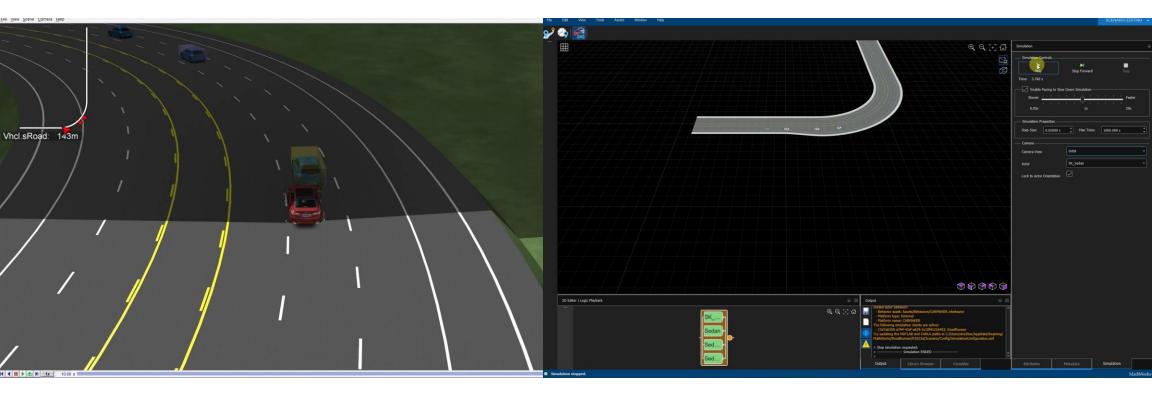


Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation



Co-Simulation framework: RoadRunner and Carmaker Why Co-simulation?

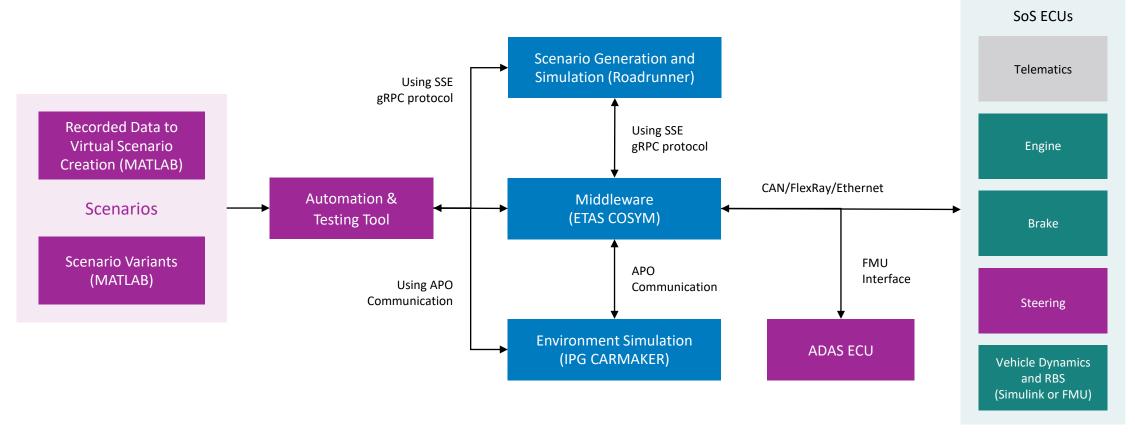


Carmaker

RoadRunner



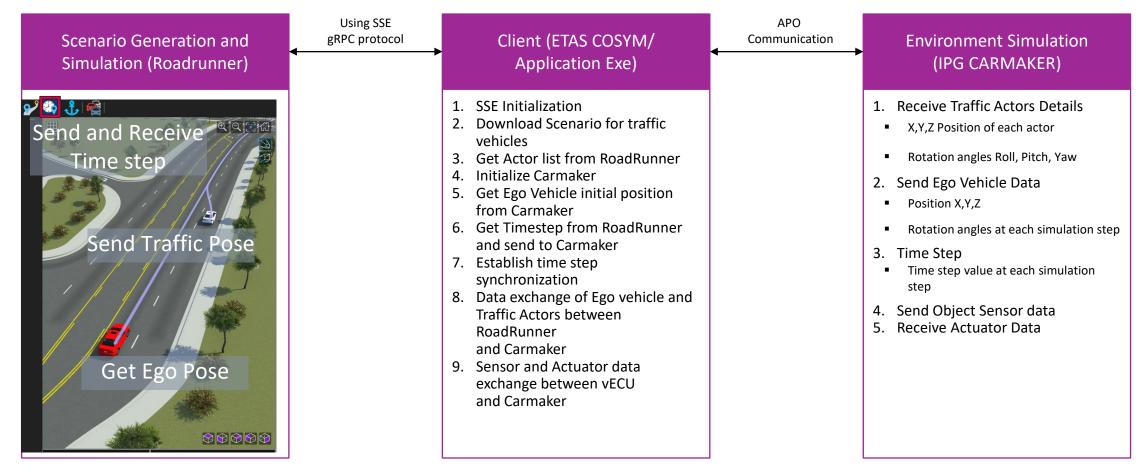
Co-Simulation framework: RoadRunner and Carmaker Scenario Simulation: Validation Setup





Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation: Data Exchange Mechanism







21 Confidential | BGSW : SDS V&V team | 01-09-2022

© Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.

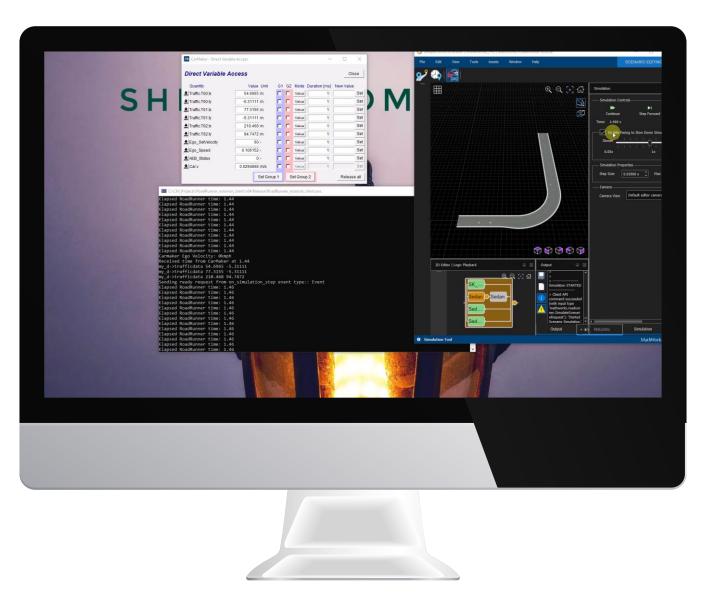




Co-Simulation framework: RoadRunner and Carmaker

Actors Position Update





23 Confidential | BGSW : SDS V&V team | 01-09-2022

© Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.



Co-Simulation framework: RoadRunner and Carmaker

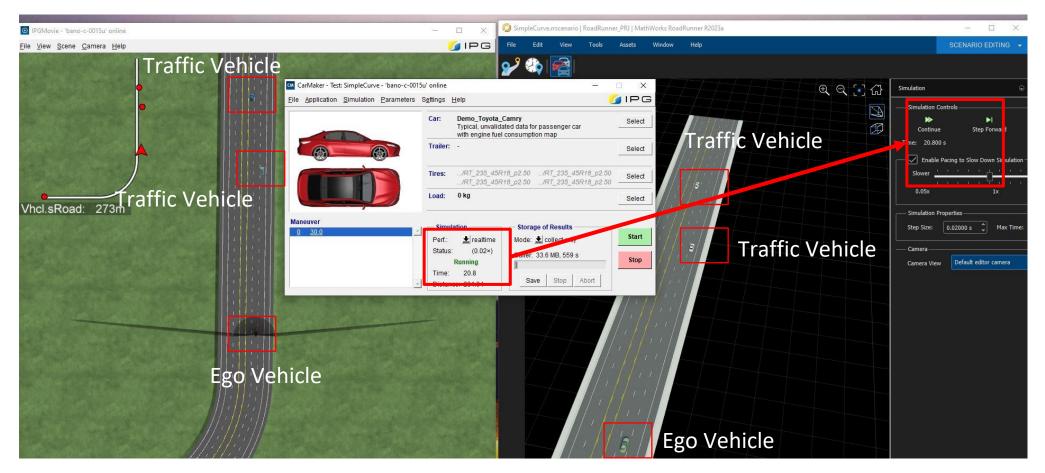
Scenario Simulation: Vehicles Position Synchronization

Elapsed RoadRunner time: 1.38 Sending ready request from on_simulation_step event Elapsed RoadRunner time: 1.38	t 🖾 CarMaker - Direct Variable Access					-		
Elapsed RoadRunner time: 1.38 Elapsed RoadRunner time: 1.38 Elapsed RoadRunner time: 1.38	Direct Variable Access					Close		
Elapsed RoadRunner time: 1.38	Quantity	Value Unit	G1	G2	Mode Dura	tion [ms]	New Value	
Elapsed RoadRunner time: 1.38 Elapsed RoadRunner time: 1.38	± Traffic.T00.tx	53.6236 m	Г	Г	Value	1	Set	
Elapsed RoadRunner time: 1.38	Traffic.T00.ty	-5.31111 m	Г	Г	Value	1	Set	
Elansed BoadBunnen time: 1,38 Carmaker Ego Velocity: 0kmph	▲ Traffic.T01.tx	76.2426 m		Г	Value	1	Set	
Received time from CarMaker at 1.38	Traffic.T01.ty	-5.31111 m	Г	Г	Value	1	Set	
my_d->trafficdata 53.6236 -5.31111 my_d->trafficdata 76.2426 -5.31111	▲ Traffic.T02.tx	210.468 m	Г	Г	Value	1	Set	
my_d->trafficdata 210.468 95.8201	▲ Traffic.T02.tv	95.8201 m		Г	Value	1	Set	
Sending ready request from on_simulation_step event Elapsed RoadRunner time: 1.4	Lego_SetVelocity	60 -		Ē	Value	1	Set	
Elapsed RoadRunner time: 1.4	Ego_Serverocity Ego_Speed	0.106283 -		F			Set	
Elapsed RoadRunner time: 1.4	1000			1	Value	1		
Elapsed RoadRunner time: 1.4 Elapsed RoadRunner time: 1.4	▲ AEB_Status	0 -	1	Γ	Value	1	Set	
Elapsed RoadRunner time: 1.4	<u>★</u> Car.v	0.0295232 m/s			Value	1	Set	
Elapsed RoadRunner time: 1.4 Elapsed RoadRunner time: 1.4	Set Grou			up 1 Set Group 2			Release all	
Elapsed RoadRunner time: 1.4				-				
Elapsed RoadRunner time: 1.4								
Elapsed RoadRunner time: 1.4 Elapsed RoadRunner time: 1.4								
Elapsed RoadRunner time: 1.4							×	

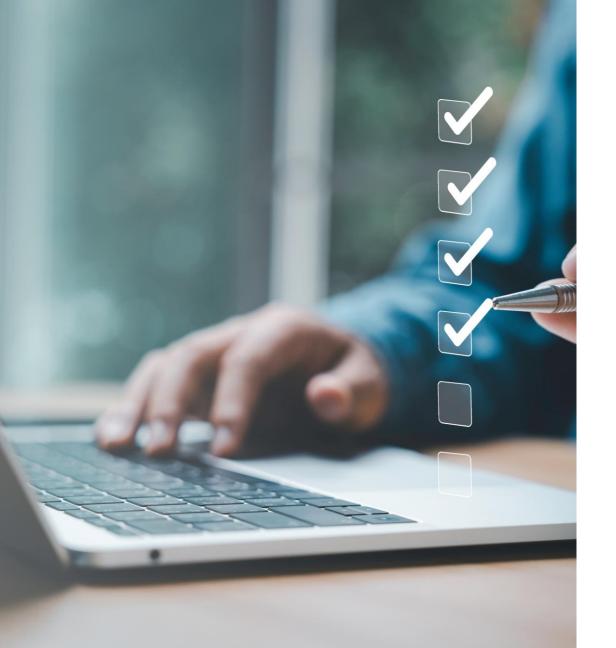


Co-Simulation framework: RoadRunner and Carmaker

Scenario Simulation: Time Synchronization







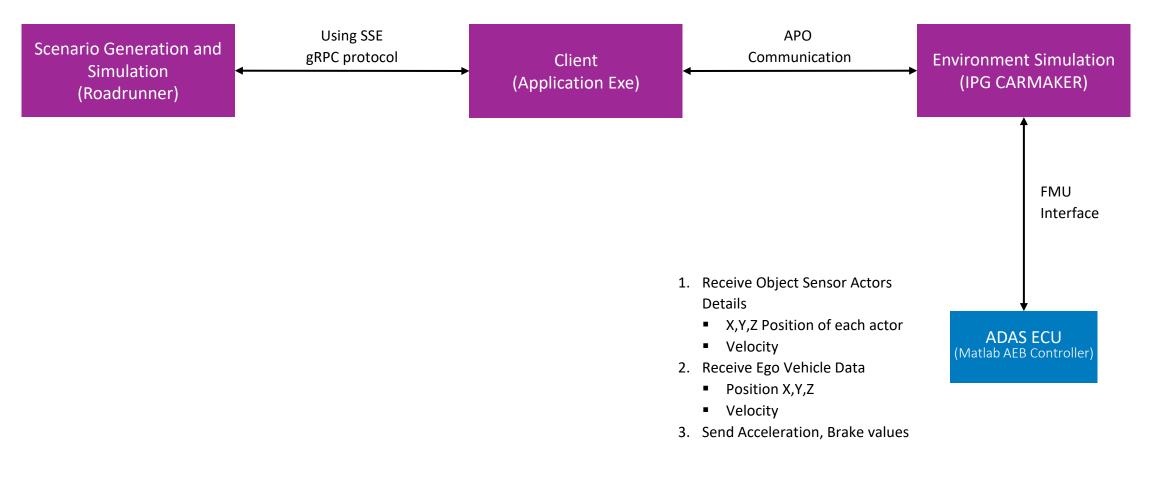
Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation



Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: Approach 1 using Visual Studio





Co-Simulation framework: RoadRunner and Carmaker AEB Controller Validation: FMU inside Carmaker

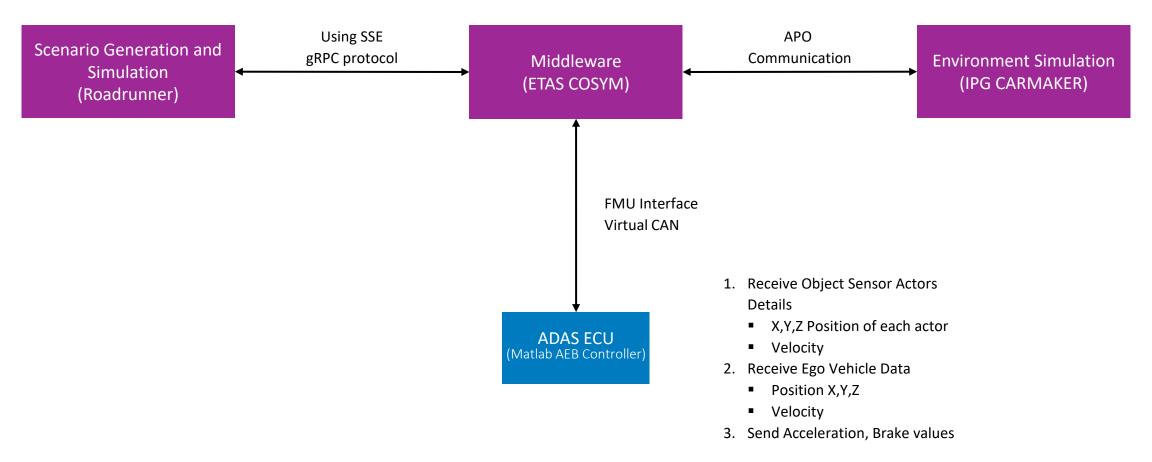




© Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.

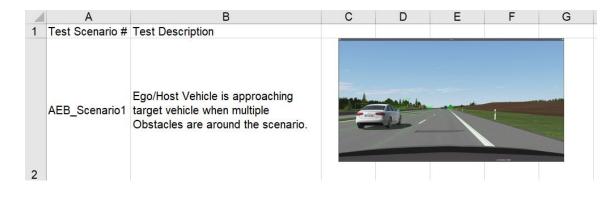


Co-Simulation framework: RoadRunner and Carmaker AEB Controller Validation: Approach 2 using ETAS COSYM

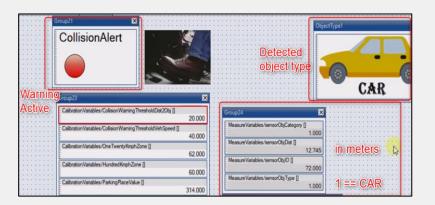




Co-Simulation framework: RoadRunner and Carmaker AEB Controller Validation: ETAS COSYM Labcar Experiment



UUT→ Front object detection and warning





30 Confidential | BGSW : SDS V&V team | 01-09-2022

© Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.



Co-Simulation framework: RoadRunner and Carmaker

Test Automation: Robot Framework

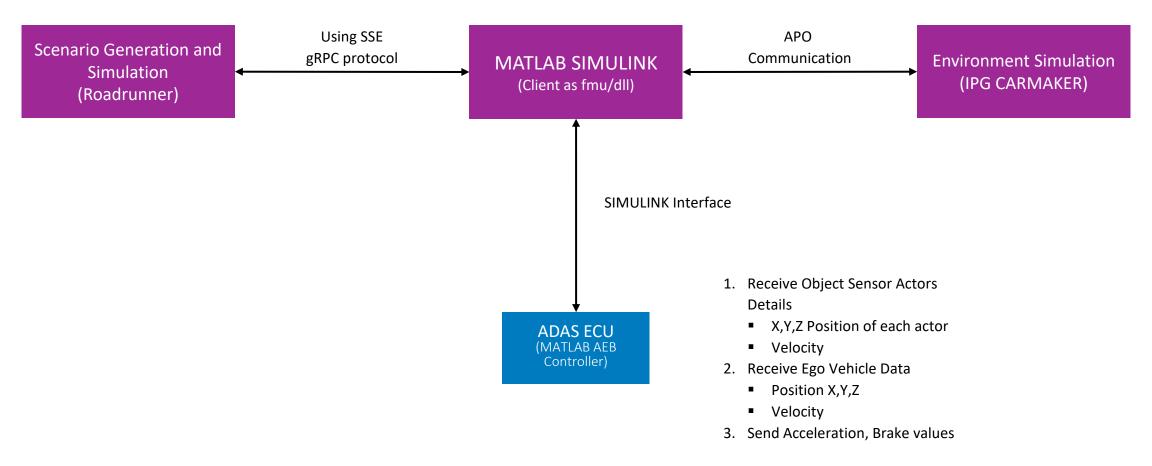
Dirticitie • Contingency 1 • Southermore 2 • Contingency 2 • Abistive theory 1 • Southermore 2 • Control Contecont Contecont Control Control Contecont Control Cont	Image: Section Decoded Image: Section Decoded Image: Section Decod	刘 File Edit Selection View	Go Run Terminal Help CosimDemo.robot - ADAS-VnV - Visual Studio Code	
• piculaty i ** Settings *** • outuby i ibbrary /libraries/Roadbunner/Protos/Roadbunner.py *** >	 bochby/ if if	EXPLORER ···	CarMaker.py 1 CosimDemo.robot ×	⊳~ □
• Customissions py • Customissions py • rets • _pycache • @ [quantities] Driver.Steer.Ang Car, y DH.Broke • _pycache • majeclobat • Carbodismonet Cosim Demo • Carbodismonet Cosim Demo • Cosim/Democabet • Carbodismonet Dirik is a sample RTF test case to demonstrate Carboker and Roadflummer co-Simulation • robotist • Carbodismonet Dirik is a sample RTF test case to demonstrate Carboker and Roadflummer co-Simulation • robotist • Dirik is a sample RTF test case to demonstrate Carboker and Roadflummer co-Simulation • robotist • Dirik is a sample RTF test case to demonstrate Carboker and Roadflummer co-Simulation • Reymbolic found in document • Dirik is a sample RTF test case to demonstrate Carboker and Roadflummer co-Simulation • Reymbolic found in document • Export Scenario Dirik is crivers/dure/wex/projects/Pomo/Scenario/SimpleCurve.rrscenario • Sigetors) = GetActors • Gifterors) • Gifterors) = GetActors • Gifterors) • Gifterors) = GetSimend Info •	 Communitationary of ended Unity with the second of the seco	✓ PlotLib.py > outputs	1 *** Settings *** 2 Library/libraries/CarMaker.py	30 ¹² SUBALNESS METALENSE METAL
 pycache or my pirotet GarWaker and RoadRunner Cosim Demo CarWaker and RoadRunner cosimulation Frequimentation Outmant and the project D://GaadRunner_Projects/Demo/Scenario/SimpleCurve.rrscenario Load RR Scenario D:/RoadRunner_Projects/Demo/Scenario/SimpleCurve.rrscenario Export Scenario Files C:/Users/dvc2kor/workspace/ADAS-VW//outputs/Export/ CosimDemo S(actors) = GetActors S(actors) = GetSimulation S(result) = Get Simend Info Log \$(result) = Get Simend Info		CustomListener.py		
CosimDemorabet Frequimentstat CosimDemorabet For the first set a sample RTF test case to demonstrate CarMaker and Roadkunner co-Simulation CosimDemorabet No symbols found in diad RR Project D:/Koadkunner_Projects/Demo Load RR Scenario/SimpleCurve.rrscenario Export Scenario Files C:/Users/dve2kor/workspace/ADAS-VNV/outputs/Export/ CosimDemo Since State S	Cosmbemozobet Cosmbet Cosmbemozobet Cosmbet Cosmb	> _pycache_		
Image: Control of the second of the secon	<pre></pre>	☐ © CosimDemo.robot		
Working 16 Load RR Scenario D:/RoadRunner_Projects/Demo/Scenario/SimpleCurve.rrscenario No symbols found in TosimDemo.robot 13 Export Scenario Files C:/Users/dve2kor/workspace/ADAS-VnV/outputs/Export/ CosimDemo Sectors 10 f(actors)= GetActors 10 f(actors)= Load CN Project D:/CarMaker_Projects/RoadRunner_Carmaker11_Server Load CN Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server/Data/TestRun/SimpleCurve Configure Variation f(quantities) normal erg buffer 1 Run Simulation 10 f(result)= Get Simend Info 1 1 33 Log f(result)= Get Simend Info 1 1 1 34 Image: Simend Info 1 1 1 1 1 1 34 Image: Simend Info 1 1 1 1 1 1 1 1 35 Image: Simend Info 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Vulne 16 No symbole found in document Load RR Scenario D:/RoadRunner_Projects/Demo/Scenario/SimpleCurve.rrscenario CosimDemotobot 10 S(actors) Export Scenario Export Scenario Load CM Project D:/CarMaker_Projects/RoadRunner_Carmaker11_Server Load CM Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server Load CM Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server Load CM Testrun Signes/Carmaker11_Server Load Server Load Server Load Server Load Server Signes/Carmaker11_Server Server Signes/Carmaker11_Server Load Server Signes/Carmaker11_Server Server Signes/Carmaker11_Server Signes/Carmaker11_Server Signes/Carmaker11_Server	robot.bat		
<pre>\${actors}:= GetActors Lg \${actors} Lg \${actors} Log \${actors} Log \${actors} Log \${actors} Load CM Project D:/CarMaker_Projects/RoadRunner_Carmaker11_Server Load CM Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server/Data/TestRun/SimpleCurve Configure Variation \${quantities} normal erg buffer 1 Run Simulation \${result}:= Get Simend Info Log \${result} } TIMELINE </pre>	<pre> \$</pre>	No symbols found in	16 Load RR Scenario D:/RoadRunner_Projects/Demo/Scenario/SimpleCurve.rrscenario 17	
<pre> Load CM Project D:/CarMaker_Projects/RoadRunner_Carmaker11_Server Load CM Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server/Data/TestRun/SimpleCurve Load CM Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server/Data/TestRun/SimpleCurve Configure Variation \${quantities} normal erg buffer 1 Run Simulation S{result}= Get Simend Info Log \${result} Log \${result} Journal erg buffer 1 Log \${result} Log \${result} Journal erg buffer 1 Journal erg buffe</pre>	Image: Second state of the	'CosimDemo.robot'	20 \${actors}= GetActors 21 Log \${actors}	
27 Run Simulation 29 \${result}= Get Simend Info 31 Log \${result} 33 34 > TIMELINE > TIMELINE	27 Run Simulation 29 \${result}= 31 Log \${result} 32 Log \${result} 33 J 34 Log \${result} 33 Log \${result} 34 Log \${result} 34 Log \${result} 34 Log \${result}		23 Load CM Project D:/CarMaker_Projects/RoadRunner_Carmaker11_Server 24 Load CM Testrun D:/CarMaker_Projects/RoadRunner_Carmaker11_Server/Data/TestRun/SimpleCurve	
30 \${result}= Get Simend Info 31 Log \${result} 33 34	30 \${result}= Get Simend Info 31 32 Log \${result} 33 34		27 28 Run Simulation	
33 34 34 35 34 34 34 35 34 <p< td=""><td>33 34 ⊗ > TIMELINE > TIMELINE > 0 ∆ 1 Ln 32, Col 19 Spaces: 2 UTF-8 CRLF Robot Framework</td><td></td><td>30 \${result}= Get Simend Info</td><td></td></p<>	33 34 ⊗ > TIMELINE > TIMELINE > 0 ∆ 1 Ln 32, Col 19 Spaces: 2 UTF-8 CRLF Robot Framework		30 \${result}= Get Simend Info	
総 > TIMELINE				
> IMELINE	Image: Spaces: 2 UTF-8 CRLF Robot Framework	8		
✓ ⊗ 0 Å 1 Ln 32, Col 19 Spaces: 2 UTF-8 CRLF Robot Framework Å		جمع ۲imeline ک		
	5 V&V team 01-09-2022		Ln 32, Col 19 Spaces: 2 UTI	-8 CRLF Robot Framework 🔗

BOSCH

31 © Robert Bosch GmbH 2023. All rights reserved, also regarding any disposal, exploitation, reproduction, editing, distribution, as well as in the event of applications for industrial property rights.

Co-Simulation framework: RoadRunner and Carmaker

AEB Controller Validation: Approach 3 (Future Focus)



BOSCH

Co-Simulation framework: RoadRunner and Carmaker Benefits:

- Interactive traffic simulation ensuring a realistic traffic environment
- Accurate traffic conditions for testing different traffic scenarios





Questions?





Thank you!

