Multi-Agent Approach for AD/ADAS Country-Specific Virtual Validation using Real-World Data

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Agenda

- Introduction Regulation for Future AD L3+
- Scenario Extraction from Real-Field Data and Multi-Agent Approach
- High-Fidelity Simulation using Real-World Data
  - ✓Building Digital World from Test Data
  - ✓Perception Simulation and Corner Cases
  - ✓Country-Based Validation
- Summary and Outlook

- Virtual validation technology trends with focus of Level 3+ regulation requirements
- Introduction of IAV approaches and references for virtual validation of the future Autonomous Vehicles

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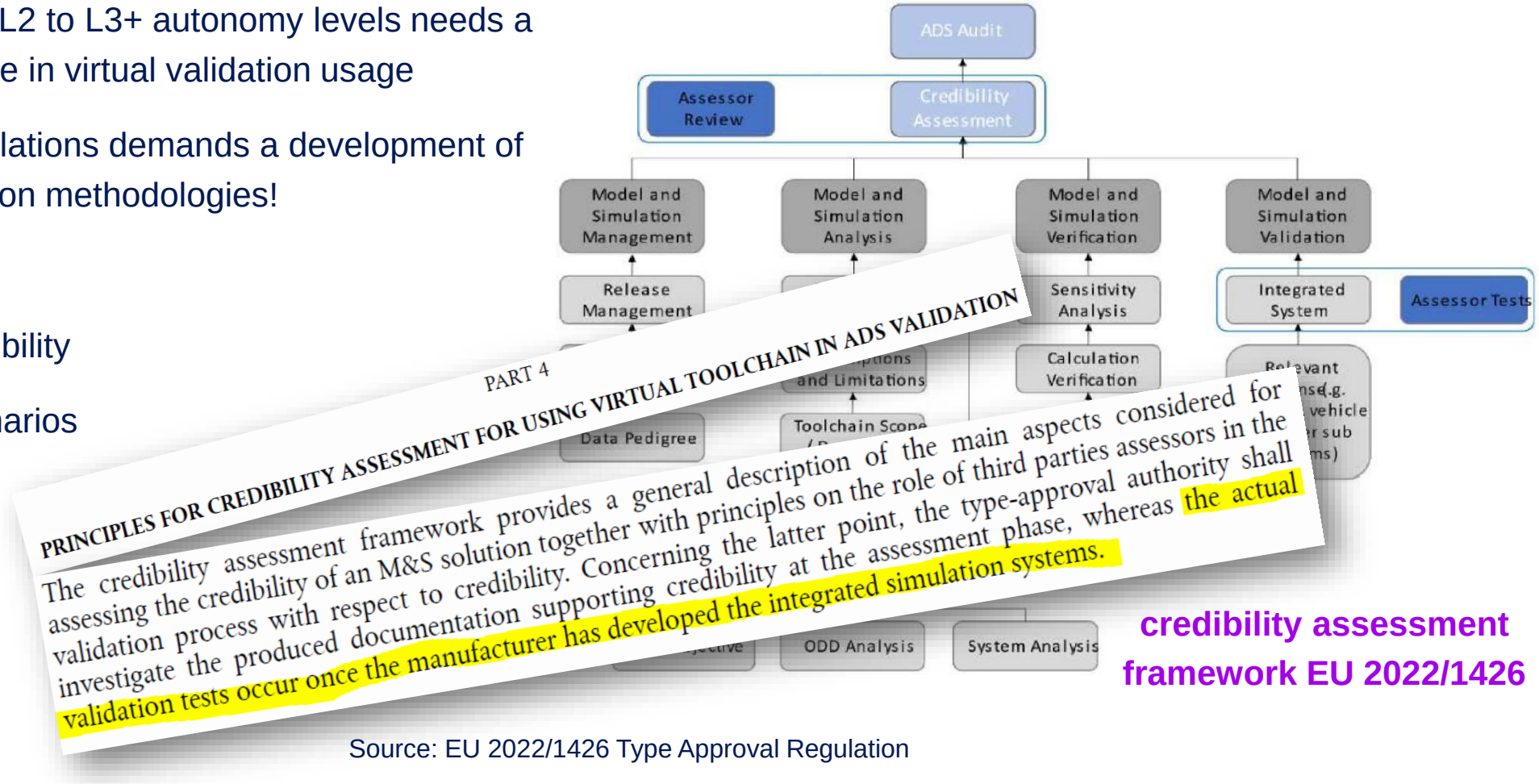
Motivation

From L2 to L3+: Significant Advancement in Virtual Validation for Development and Approval

- Progression from L2 to L3+ autonomy levels needs a significant increase in virtual validation usage
- Fulfillment of regulations demands a development of innovative validation methodologies!
- Highlight points:
  - Simulation credibility
  - Real-world scenarios



credibility assessment framework EU 2022/1426

Source: EU 2022/1426 Type Approval Regulation

Accurate 3D Environment Simulation
EU Regulation 2022/1426 and IAV Methodology

EU 2022/1426: Credibility Assessment of Sim.

- Simulation shall allow a virtualization to a degree of accuracy which matches the required fidelity level

High-Fidelity Models, especially for Perception

- Multiple open points in the regulation:
  - Which KPIs are necessary?
  - Which degree of simulation accuracy is needed?
  - Depending on use-case, how critical is a deviation?

- **IAV Methodology**:
  - ✓ High-fidelity sensor and environment models (camera, radar, lidar) incl. validation KPIs
  - ✓ Leveraging the IAV Tier1 network enables the high-quality evaluation and model integration

EU 2022/1426 Regulation and IAV Methodology
Realistic Scenarios & Coverage Corner Cases

Realistic Scenarios & Coverage Corner Cases:

- Manufacturers shall provide validation scenarios and are required to support their assumptions for concrete scenarios with evidence.
- The scenario selection used for validation shall be sufficient so that the toolchain will perform in same manner in scenarios outside of the validation scope

Scenario Extraction from Real-World

IAV Methodology:

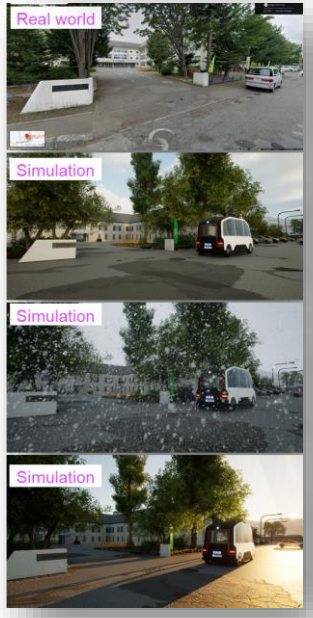
- Data-driven /test-based scenario extraction:
  - Data collection during development
  - Analysis of Real-world corner cases, accidents, etc.
  - It is important to show the “evidence of scenarios” for type approval

→ **Realistic scene and scenario is essential for virtual validation**

→ **Multiple methodologies evaluated at IAV for scenario extraction**

High Fidelity Simulation and Real-World Scenarios for Virtual Validation

Real-World Scenes & Scenarios



Vehicle Model + Sensors

Maps & Assets

MathWorks
RoadRunner
dSPACE
IPG
UNREAL ENGINE
CARLA

Versioned Driving Function

SIMULINK®

Test Control

Test Evaluation

Test Reports

SimEnv

Simulation Environment

The virtual world, executing defined scenarios.

SUT

System Under Test

The actual driving function to test

Tool

Testbench Tooling

Any further tools supporting the goal of the testbench, e.g. RESTBUS simulation

Auto

Test Automation

Automatic execution of testcases and control of tools.

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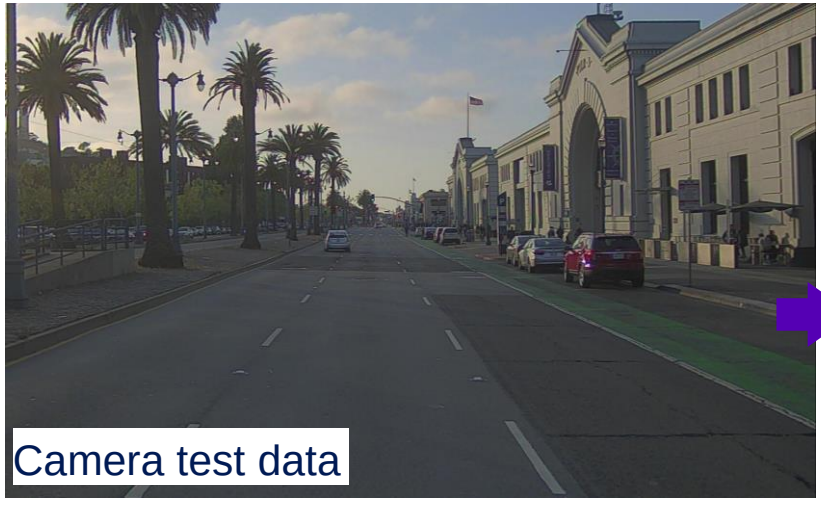
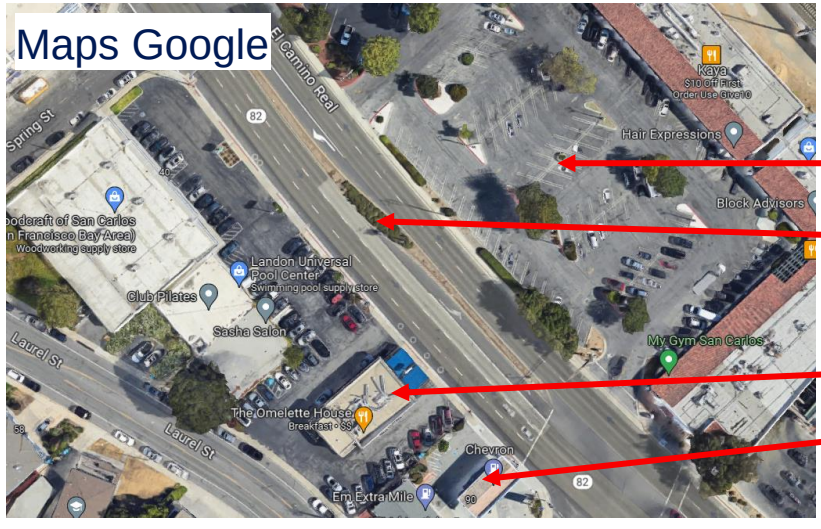
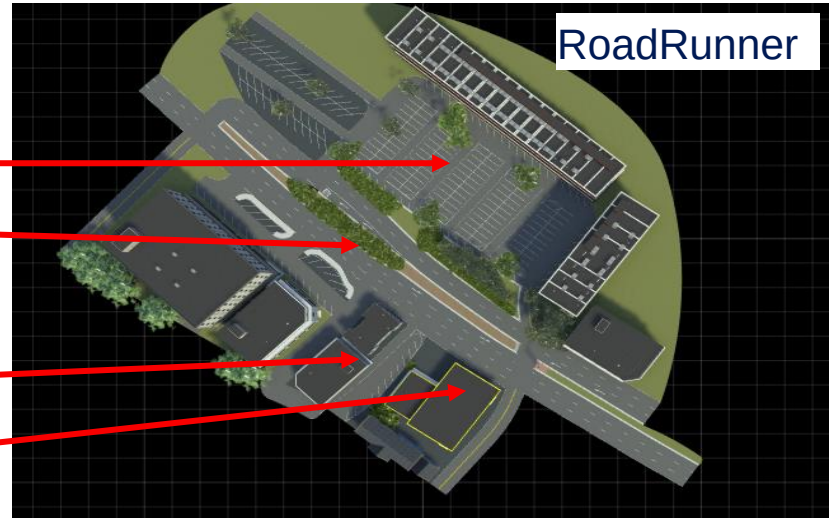
Building Digital World from Test Data

3D Environment Reconstruction from Real Test Data

- In case, test data from the challenging situation is available, the same scene will be built up in simulation
- Camera/Radar/Lidar test data are used for object detection, position, etc. to setup the model
- Beside modeling the real-world challenges, further variations can be performed
- Example results showing Digital Twin model setup from PandaSet test data in USA

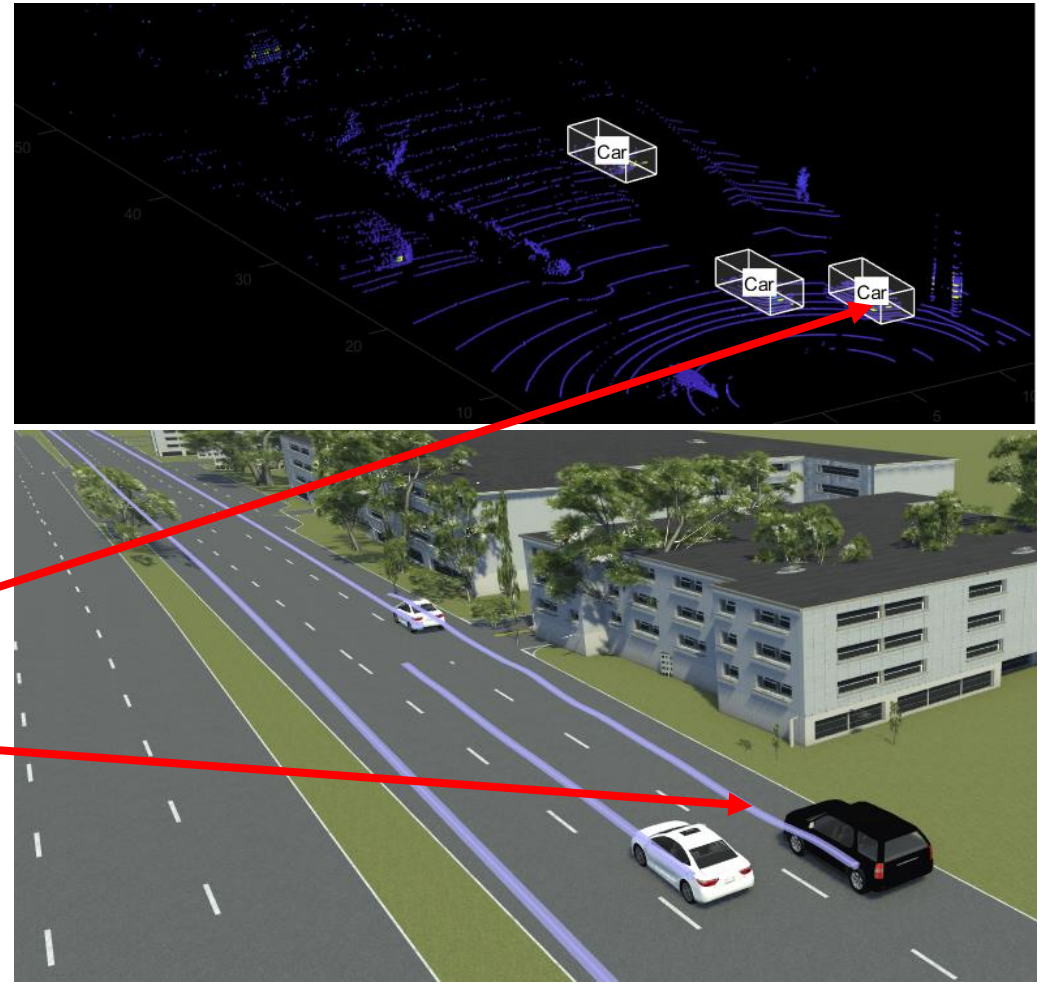






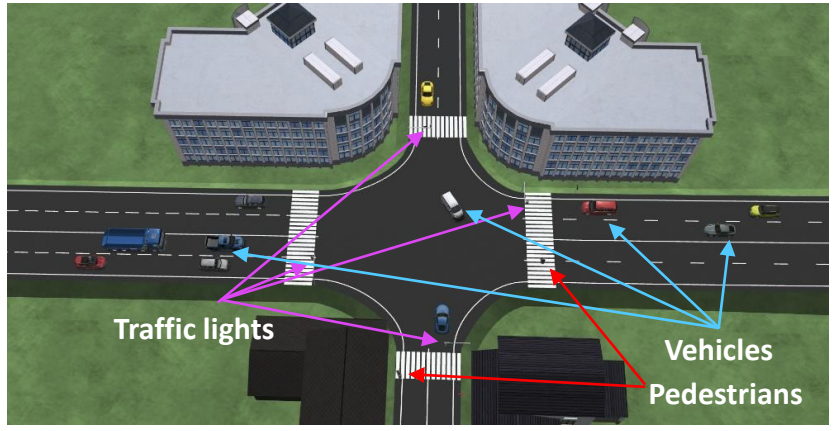
Building Digital World from Test Data
Scenario Extraction from Real Test Data

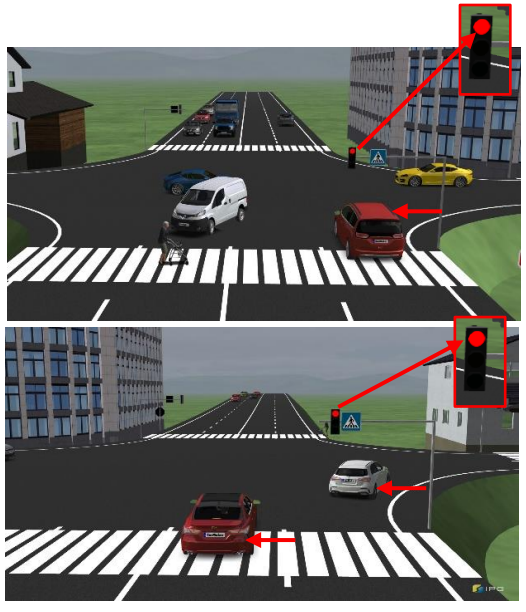
- Use of Lida/Camera data along with object detection and tracking algorithms to extract the actors trajectories and build the concrete scenario
- Reconstruction of critical situations to enhance the virtual validation of AD/ADAS
- Example results showing the extracted scene and scenario from PandaSet test data in USA



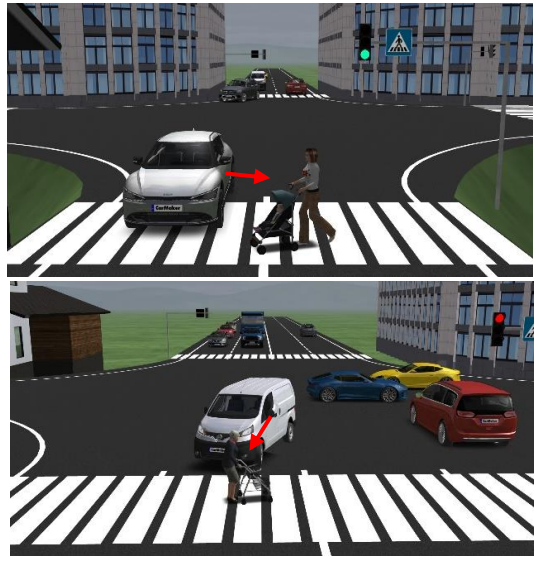
Multi-Agent Simulation for Critical Scenario Creation

- Fully automated variation of agents, assets, traffic signs/rules, etc.
- Traffic density, depending on country and rush hours possible
- Critical situations due to AD perception & control system malfunctions
- Critical situations due to traffic rule violation from other agents

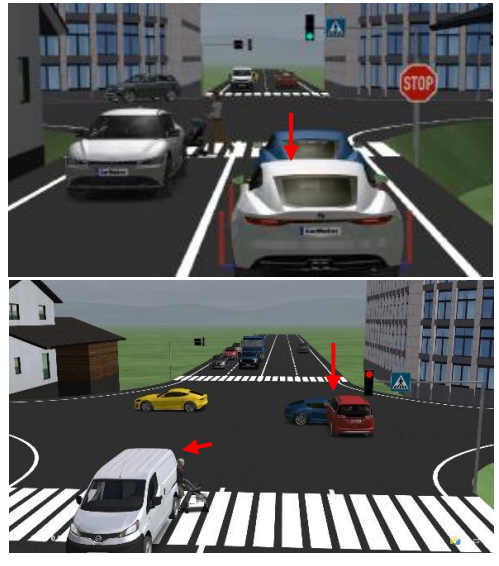




Traffic Light Violation



Critical Distance to Pedestrian



Collision / Accident

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Country-Specific Virtual Validation

From Germany to Japan and beyond

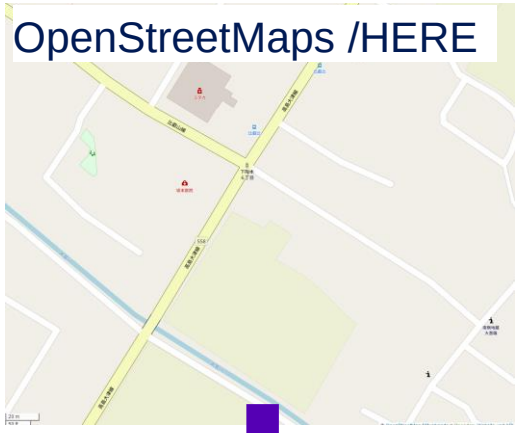
- Country-specific validation:
  From Germany to Japan and beyond
- Road layout, traffic rules/signs & lights
- Differences in driver behavior due to the country regulations, traffic and road conditions, driver age, emotional state and habits, vehicle characteristics, etc.
- Realistic modeling of environmental factors: snow, rain, fog, lighting
- Road condition in various seasons, damage of signs, construction site, etc.
- Country specific testing procedures

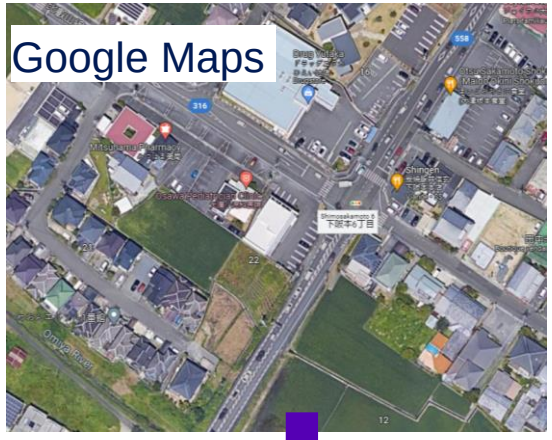
→ Efficient methodology for derivate development for global market

Virtual World Creation

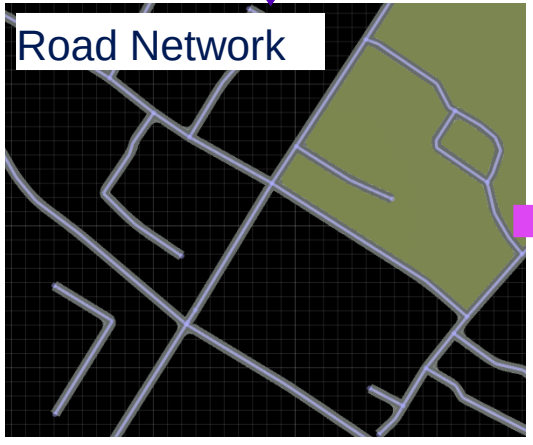
Real-World Definition of Assets and Traffic Signs

Real-World Data





Sim. Model Setup



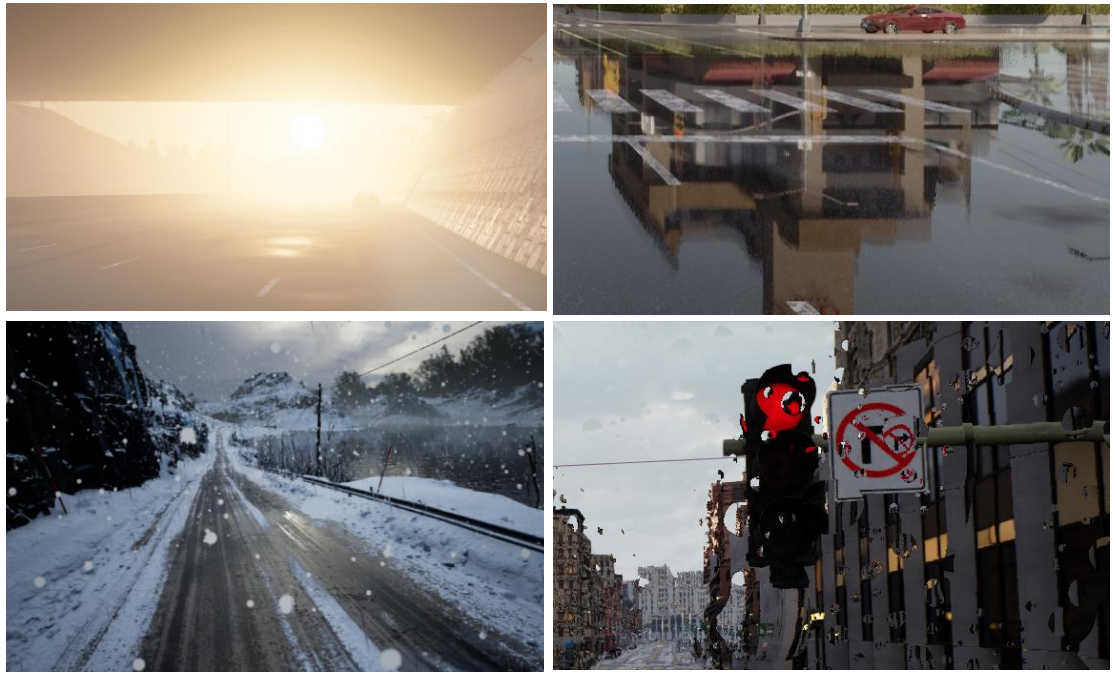
→ Example of a realistic scene setup in Ōtsu-shi (大津市) in Shiga Prefecture for country-based validation

High-Fidelity 3D Environment Simulation

Creation of Real-World Digital-Twin

- **Superior Realism with High-Fidelity Models**: Photorealistic simulation for high level accuracy
- **AI Training and Testing**: The high-fidelity simulation provide the most realistic platform for training and testing AI systems, ensuring optimal performance in Real-World scenarios.
- **Customization**: The technology also allows for the specific reconstruction of cities or junctions

Real-World Scenarios
Camera Corner Cases



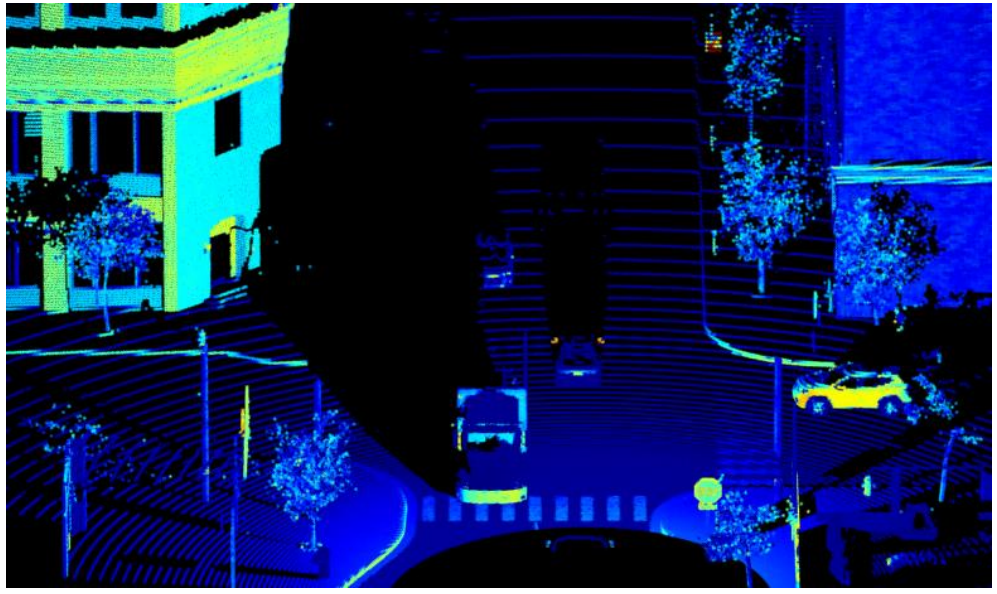
Further results: Rezaei, R., et al. „**AI-based Virtual Development Methodology for Holistic System Optimization**”, Japan SAE, Yokohama, 2023

Modeling typical camera field issues:

- There are multiple situations which are challenging for the computer vision algorithms like:
  - ✓Lightning conditions and overexposure
  - ✓Glare
  - ✓Dynamic range effects
  - ✓Strong surface reflections, e.g. due to ice or rain
  - ✓Soiling/raindrops on the camera lens or windshield
- Using a photo-realistic and “physics-based” modeling approach can best represent the complex scenarios for AI training and testing

→ **Using photo-realistic and physics-based modeling approach in the development phase improves system robustness**

Real-World Scenarios
LiDAR Sensor Corner Cases



IAV Internal Project LiDAR Simulation

- Low visibility conditions: heavy rain, fog, snow
- Dynamic and occluded objects
- Ghost reflections
- Modeling and optics:
  - Laser beam, scanning pattern, noise, power
  - Reflections, scattering, absorption
- Performance evaluation:
  - Range, resolution, accuracy, repeatability, latency etc.

→ Leveraging experiences from real-world AD/ADAS development to generate realistic corner cases

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Summary and outlook

Highlights EU 2022/1426 Type Approval Regulation:

- The “required” accuracy level of the simulation needs to be defined and “proven” by OEM
- Manufactures to provide “realistic” scenarios with “sufficient coverage” incl. “evidence”

Selected experiences at IAV:

- End-to-end testing with high sophisticated simulation models and scalable test in the cloud
- Sensor (camera, radar & lidar) modeling, perception corner cases and high fidelity 3D environment models
- Country-specific scenes and scenarios for virtual validation and derivate development: from Germany to Japan!
- Proof of concept (PoC) for the extraction of scenes and scenarios from the real-world tests
- Modification of scenes and scenarios using multi-agent approach

Outlook:

- Using AI large language models, e.g. GPT for analysis of textual test description and scenario extraction

Outlook

GPT-Powered Scene and Scenario Creation

Requirements

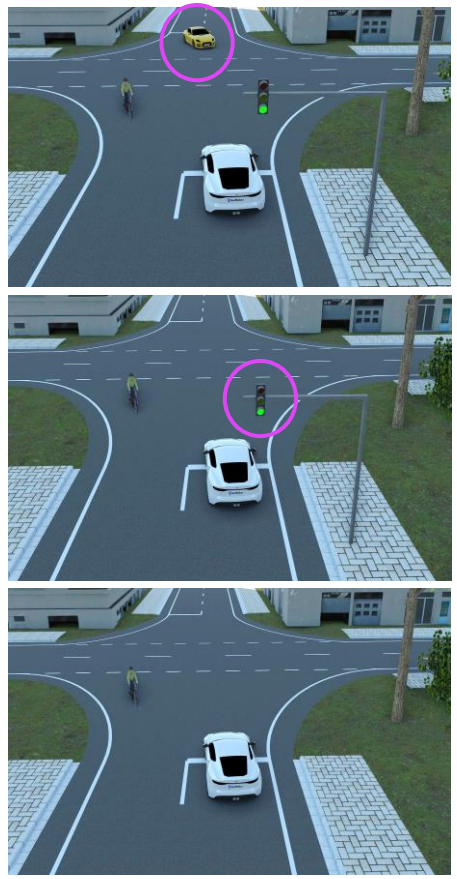
Test Case Specifications

Scenario Descriptions

Real-World Data from Testing

Feature/ Parameter Extraction

Automated Scenario Creation and Modification



Example Results

Scenario Classification

OpenX

Scenario Database

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