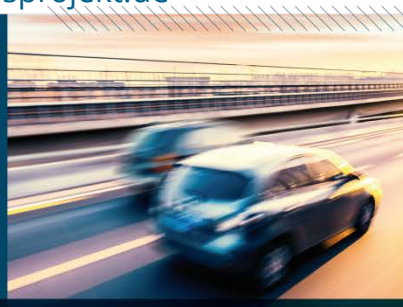
www.pegasusprojekt.de

TESTING AND SAFEGUARDING – Booth No. 20

SENSOR SIMULATION MODELS



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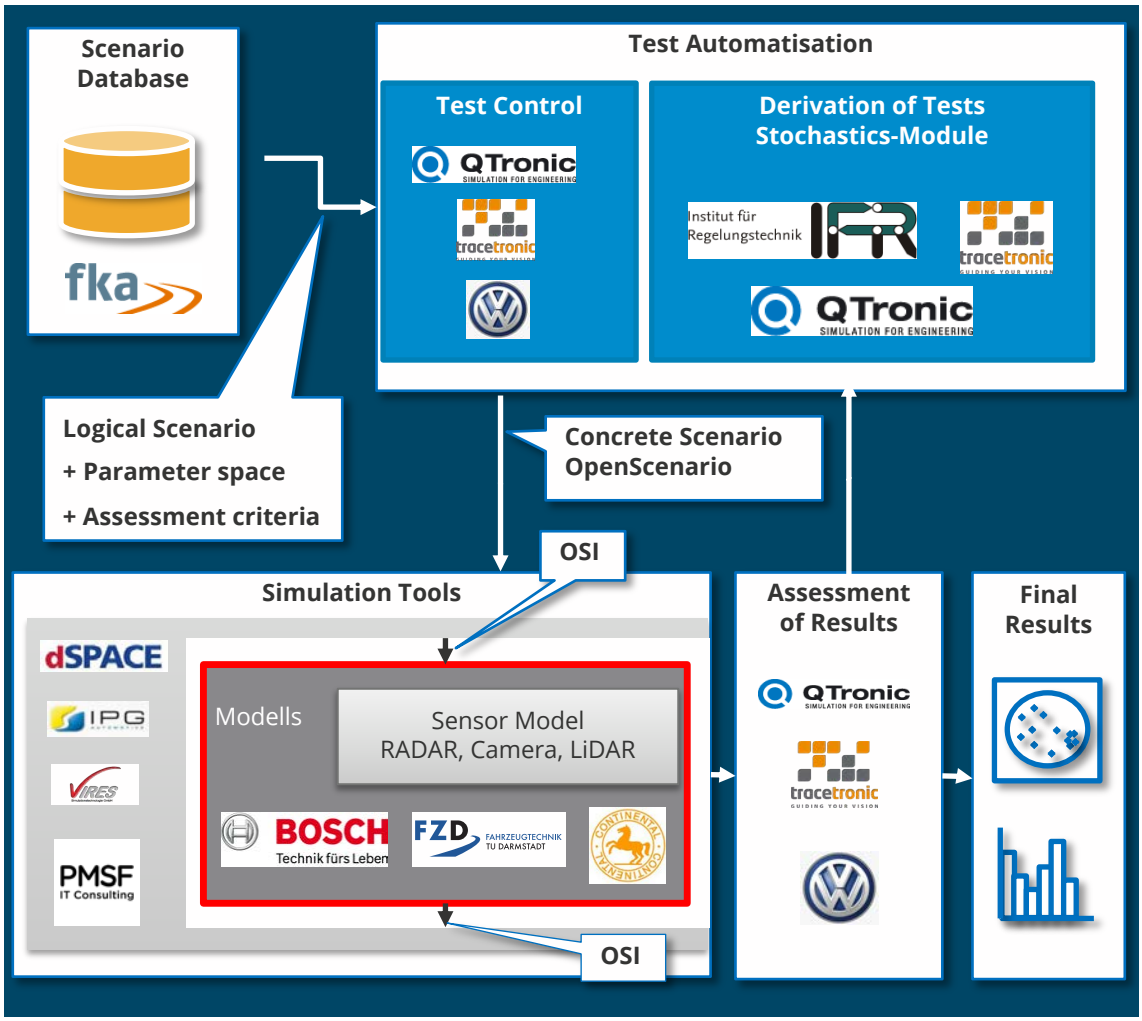
Surrounding objects and other traffic participants are sensed by systems based on radar, camera and lidar technologies. These sensor concepts generally differ in terms of their measurement performance (e.g. accuracy of position and velocity of objects, classification.) Sensor simulation models shall enable virtual testing with respect to their physical counterparts in suitable simulation environments.



Sensor models allow virtual test and validation of Automated Driving Functions and make an important contribution to the release of Automated Driving!

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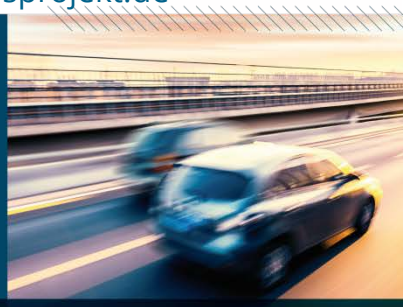

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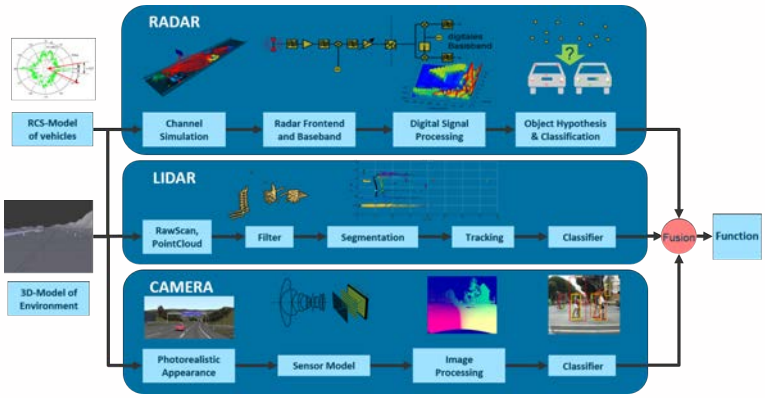
Simulation of sensor data from an environment simulation

For radar-, camera- and LiDAR-sensors models have been developed, which reflect the properties of the respective sensors:



Components of the sensor models for radar, LiDAR and camera based on their physical setup. For radar and camera the effects are modelled phenomenologically, i.e. the result of the effect is modelled.

The radar-sensor model requires a polar representation of the RCS (Radar Cross Section) of all involved vehicles in simulation.

All sensors
- Distance
- Field of View
- Masking

Radar
- Antenna diagram
- Attenuation (weather/coverage)
- Resolution (angle/distance/velocity)

Camera
- Weather conditions
- Time of day
- Optical variations (distortion, blur, vignetting)

LiDAR
- Number of scan layers, range
- Noise behaviour
- Relevance of attributes for object recognition

Example visualisation of modelled sensor data with IPG CarMaker: The blue vehicles in front are recognised and located (green frame). The text box right of the frame lists sensor specific outputs of the simulation.

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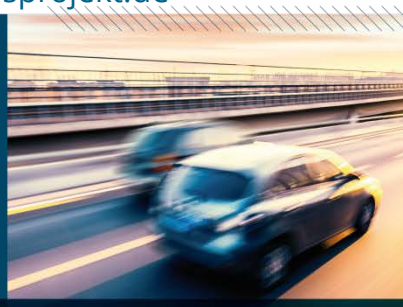
RADAR SENSOR MODEL



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Phenomenological radar sensor model

Ideal object list → radar specific properties → **Modified object list**

- **Sensor position**
- **Sensor orientation**
- **Field of View / Antenna diagram**
- **Object**
  - Occlusion
  - RCS
- **Signal attenuation**
  - Radar equation
  - Bumper
  - Rain, fog,...
- **Dynamic objects**
- **Resolution/Separability**
  - Distance
  - Angles
  - Velocity
- **Noise (phase, thermal, ...)**
- **Existence probability**

Visualization of modelled radar sensor data with IPG CarMaker: The blue vehicles in front are recognized and located at the position of the green frame. The text box right of the frame lists radar sensor specific outputs.

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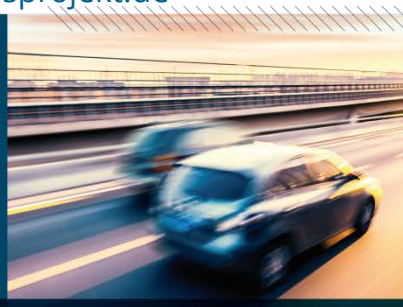
LIDAR SENSOR MODEL



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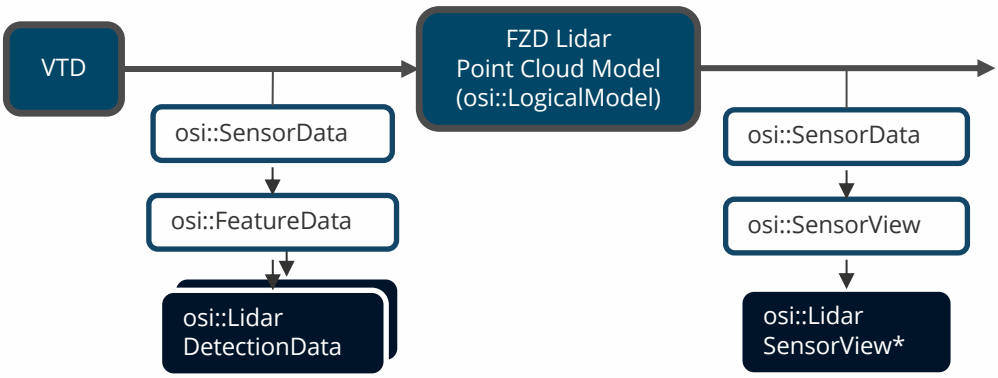
Phenomenological lidar sensor model

Ideal point cloud → lidar specific properties → **Realistic point cloud**

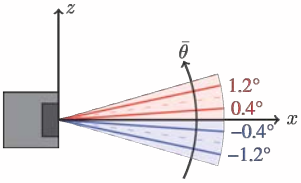


Ideal point cloud in spherical 3D sensor coordinates for two virtual lidar sensors

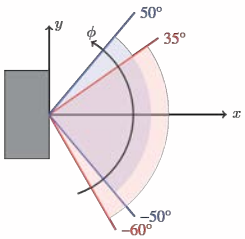
Fused point cloud in Cartesian 3D vehicle coordinates

- **Sensor position**
- **Sensor orientation**
- **Measurement range**

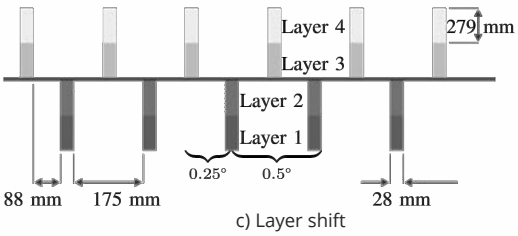
- **Noise**
- **Layer shift**
- **Beam alignment**



Lidar sensor: a) Side view



b) Top view



c) Layer shift

*Field is chosen temporarily, as there is no proper field for Cartesian point clouds in OSI, right now

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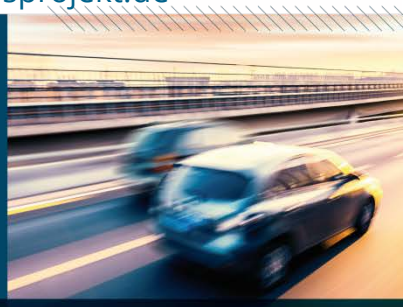
CAMERA SENSOR MODEL



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Phenomenological camera sensor model

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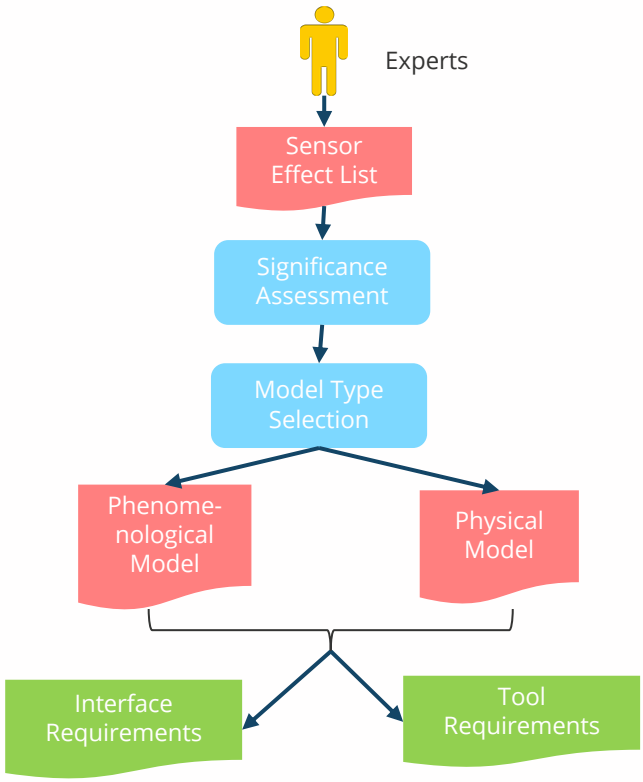
CONTINENTAL

Ideal object list → camera specific properties → **Modified object list**

→ **Model Development and Selection Strategy:**

- Driven mainly by …
  - Determination of significant sensor technology effects (e.g. vignetting)
  - Test Use Cases



→ fmi FUNCTIONAL MOCK-UP INTERFACE **OSI** …

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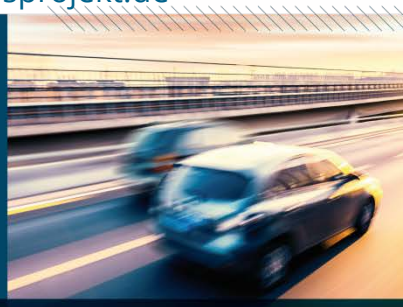
SENSOR SIMULATION MODELS
MODEL VALIDATION



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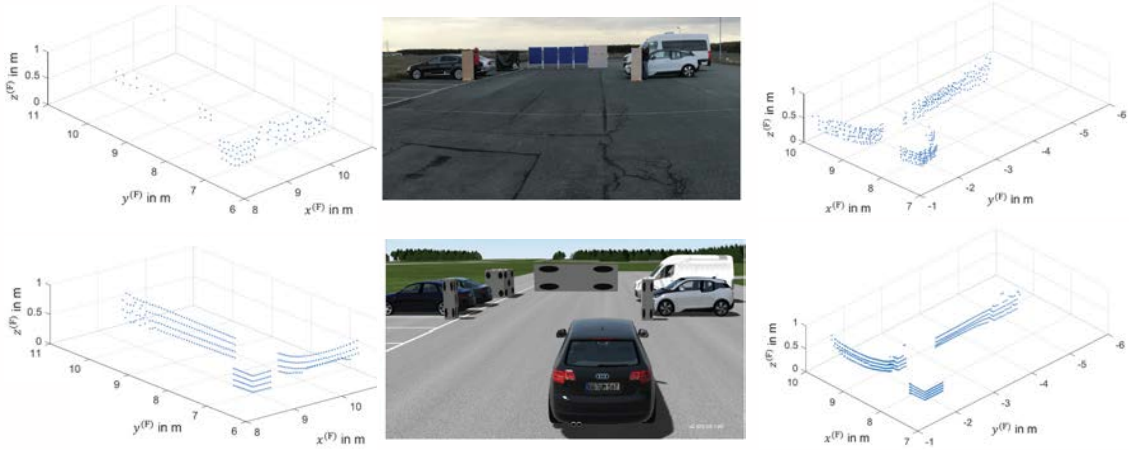
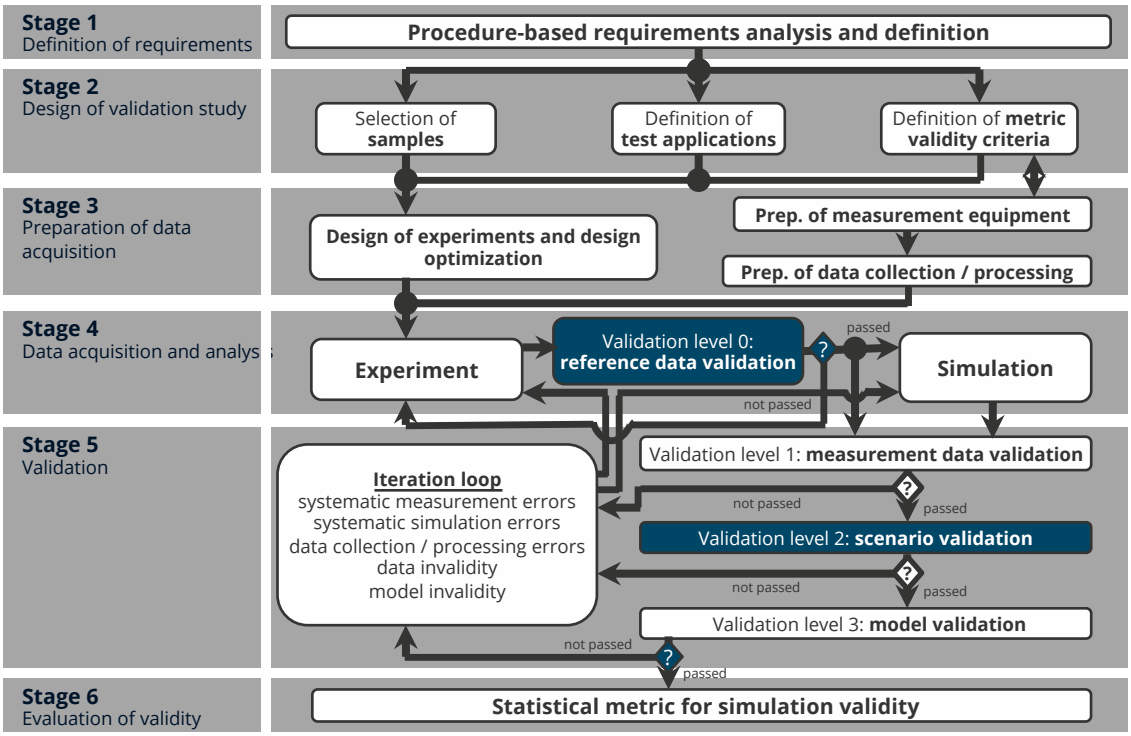
Visual inspection



Source: Moritz Berghöfer, *Generierung realer und synthetischer Sensordaten zur Validierung ...*, B.Sc. thesis, Technische Universität Darmstadt, 2019.

Objective quality assessment by statistical validation



Based on: Michael Viehof, *Objektive Qualitätsbewertung von Fahrdynamiksimulationen durch statistische Validierung*, Ph.D. thesis, Technische Universität Darmstadt, 2018

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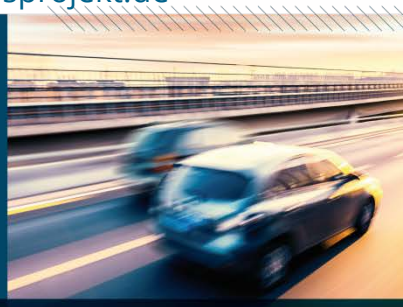
SENSOR SIMULATION MODELS
STANDARDIZATION & HARMONIZATION



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PMSF IT Consulting

Cost-effective and reliable simulation architectures need standardized interfaces: The PEGASUS project has enabled the Open Simulation Interface (OSI) initiative to standardize sensor simulation interfaces.

To enable faithful information transfer, harmonization across standards and standardization bodies is essential: As part of the PEGASUS project, harmonization activities between OSI and the upcoming ISO 23150 standard for in-vehicle sensor data formats have been started, as has the harmonized transition of OpenSCENARIO, OpenDRIVE/OpenCRG and OSI to the ASAM standardization body.

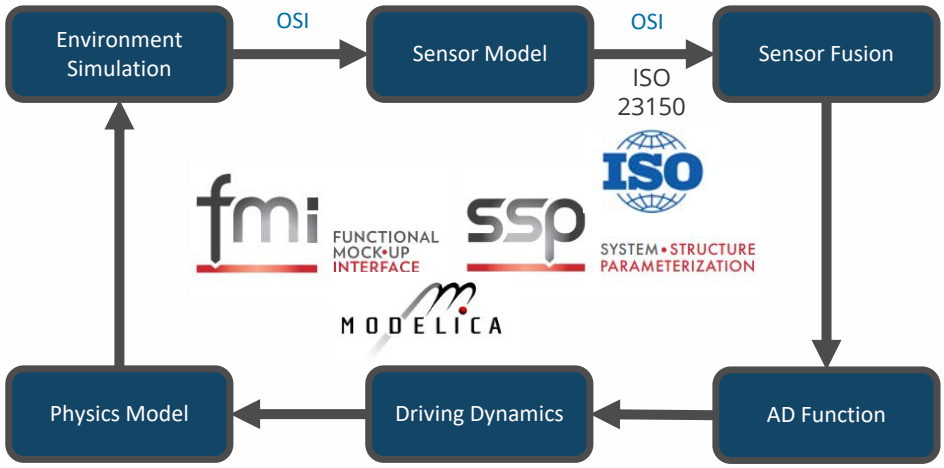
ASAM
OpenSCENARIO
OpenDRIVE
OpenCRG

Navigation Data Standard

Open Simulation Interface (OSI)

OCG cityGML

glTF



Harmonization across relevant standards and standardization bodies for sensor simulation enables faithful and reliable simulation for validation of automated driving.

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