Comparing OTA/ViL and Real World Measurement Radar Data

German-Japan joint virtual validation methodology for intelligent driving systems – VIVID

Lukas Elster (TU Darmstadt)
Aidar Khakimov (TU Ilmenau)

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DIVP™

VIVALDI

Outline

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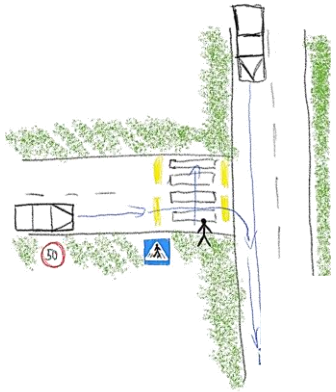
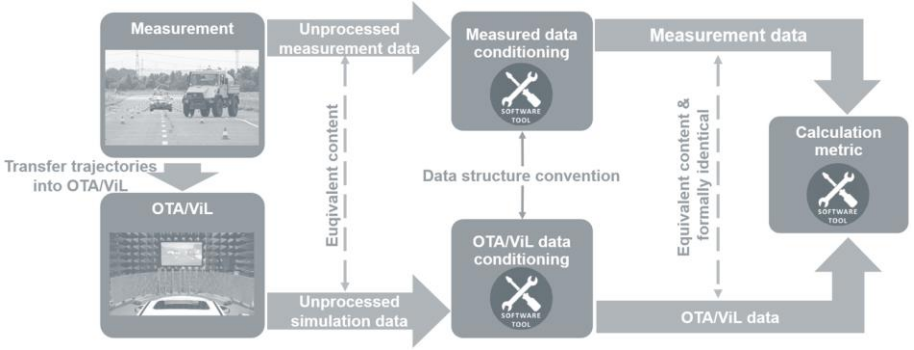
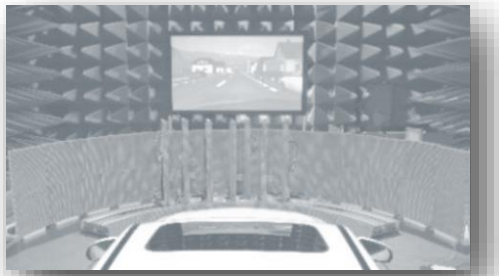
Introduction & Motivation

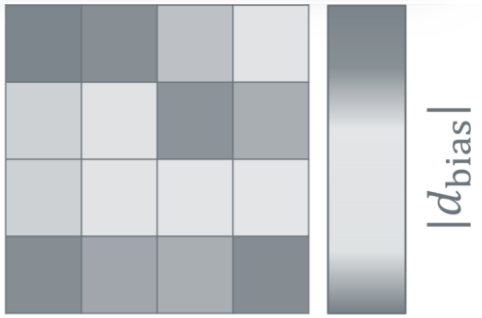


Methodology





Experimental setup



Evaluation

Safety Assessment of Automated Driving Functions

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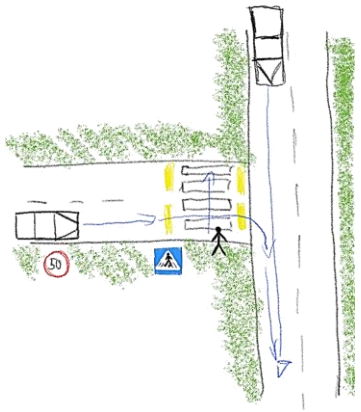
1. Distance-based → scenario-based



2. Real environment → virtual environment

3. How X is X enough?

X = Realistic, evident, consistent, justifiable, credible, **safe**

4. Virtual verification and validation based on harmonized global R&D and standardization efforts

PEGASUS FAMILY · VERIFICATION VALIDATION METHODS · SET Level · DIVP · jama · SAKURA · ASAM · IEEE · ISO

Adapted source: M. Hein et al.: *German research approach towards AD safety assurance*, Keynote SIPadus Workshop 2022, Kyoto, 2022

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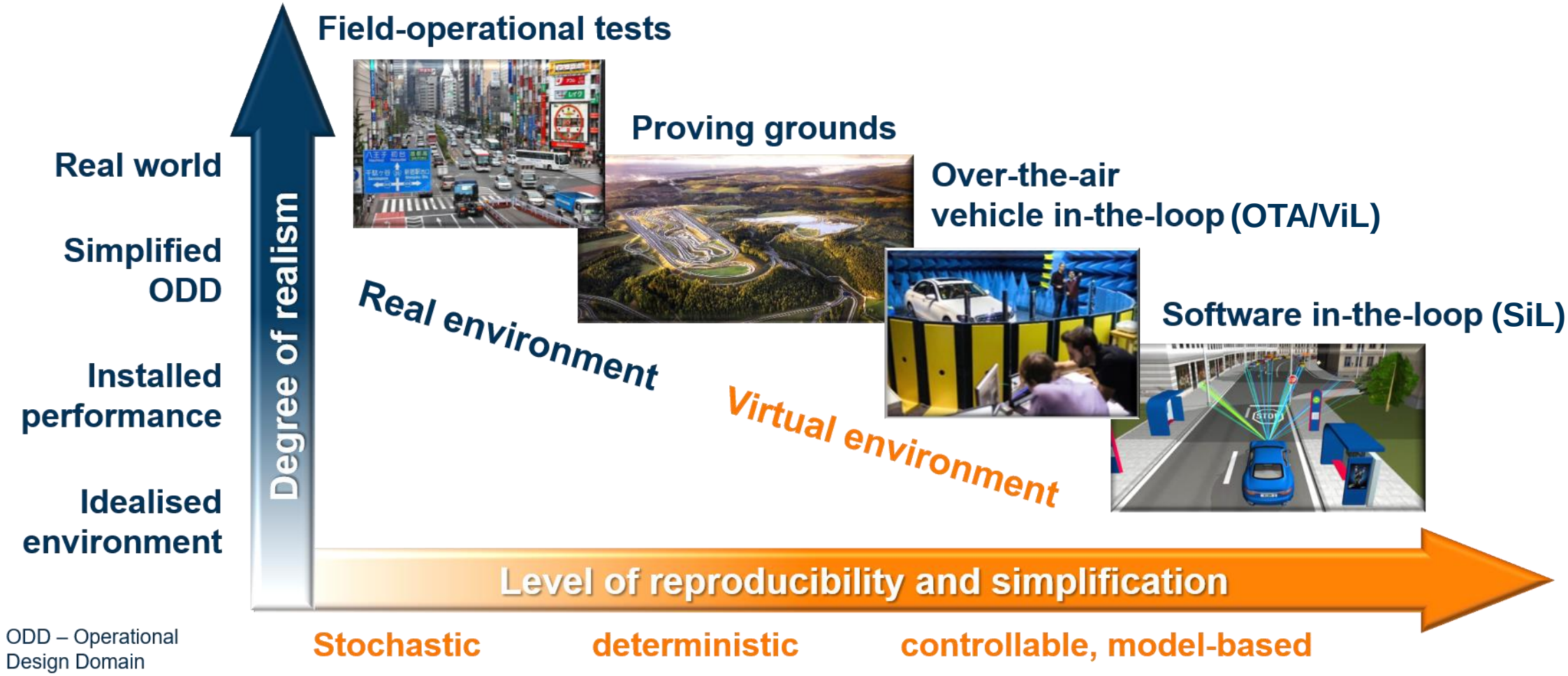
Environment Overview for Safety Assessment



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State of the Art

Radar sensor in OTA/ViL for scenario-based virtual safety validation of automated driving

Intended usage:

- Testing and development of algorithms, models, and functions (e.g. object detection, trajectory planner)
- Objective validity statement of radar sensors in OTA/ViL tests
- Safety assurance for automated driving functions

Validation procedure of radar sensors in OTA/ViL tests

State-of-the-art:

- Metric based analysis by comparison of real and OTA/ViL data
- Hypothesis tests to prove statistical properties
- Expert knowledge driven and subjective process due to result interpretation

How do we objectively measure the OTA/ViL capabilities based on measurements?

Adapted source: M. Viehof: *Objektive Qualitätsbewertung von Fahrdynamiksimulationen durch statistische Validierung*, PhD Thesis, TU Darmstadt, Darmstadt, 2018

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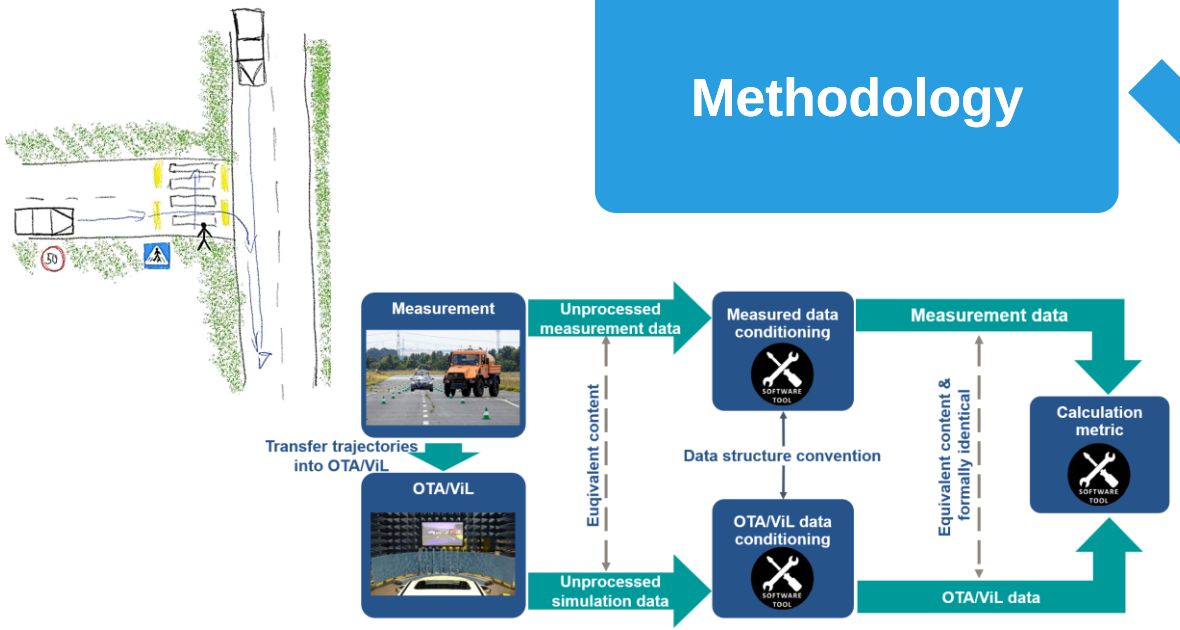

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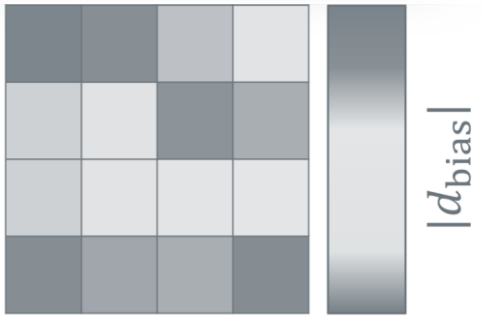

Evaluation

Validation Methodology of Radar Detection Data

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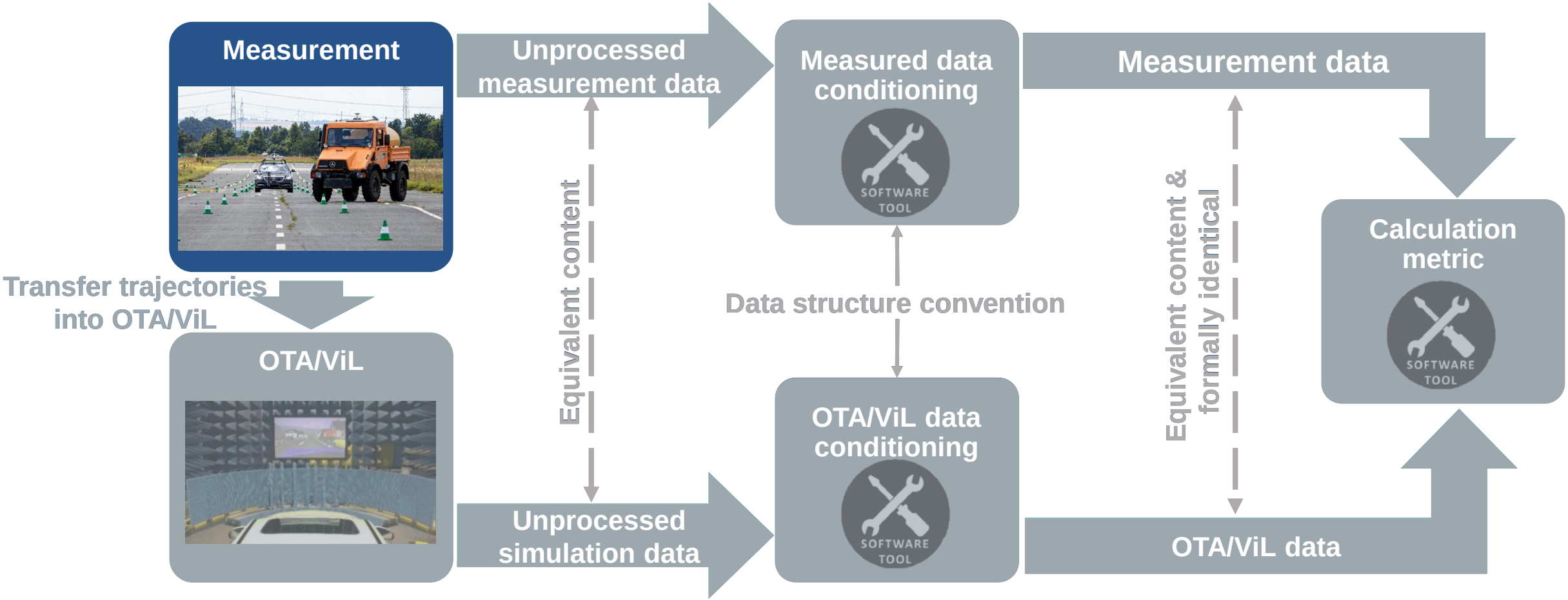

Adapted source: M. Viehof: *Objektive Qualitätsbewertung von Fahrdynamiksimulationen durch statistische Validierung*, PhD Thesis, TU Darmstadt, Darmstadt, 2018

Experimental Setup OTA/ViL Validation

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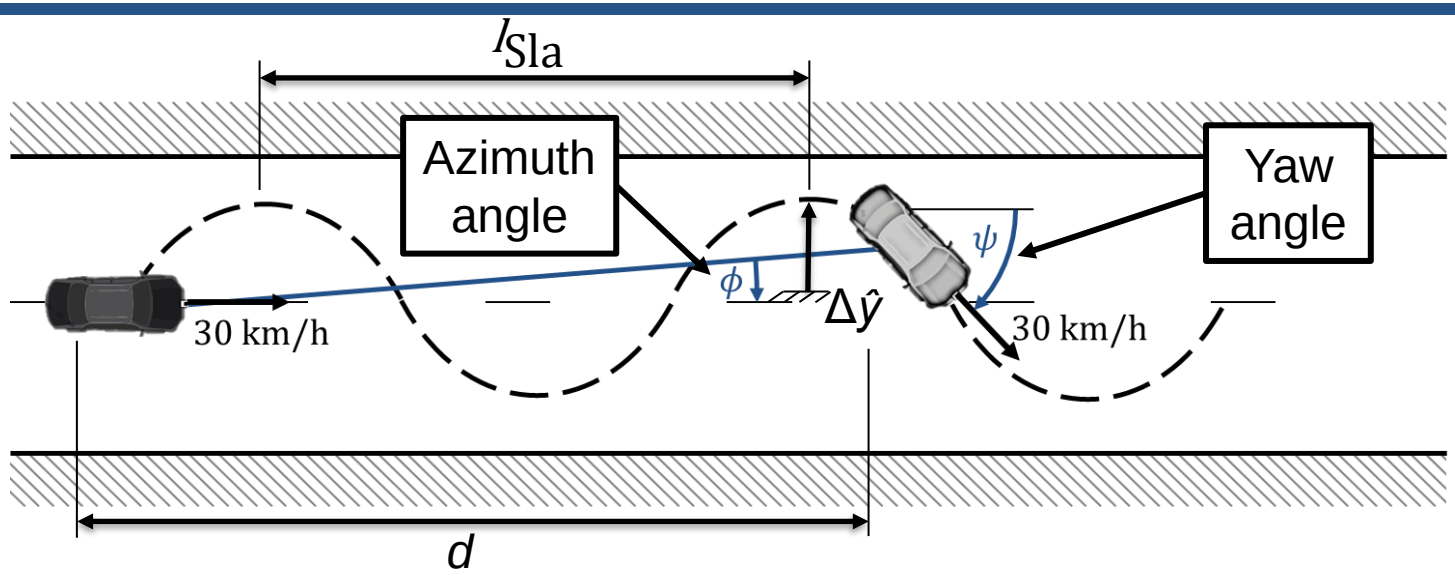
Source: M. F. Holder: *Synthetic Generation of Radar Sensor Data for Virtual Validation of Autonomous Driving,* PhD Thesis, TU Darmstadt, Darmstadt, 2021



Parameter	Distance d	Amplitude $\Delta\hat{y}$	Period length l_{Sla}
Value	60 m – 80 m	5 m	71 m
Dependency to related value of interest	ϕ	ϕ ψ	ψ

What is the effect of the slalom drive onto the RCS σ and position distribution of the radar detection data in an OTA/ViL testbed?

Source: M. Rapp: *Messkampagne zur Bestimmung der winkelabhängigen RCS-Profile von Verkehrsteilnehmern,* B.Sc. Thesis, Darmstadt, 2021

Experimental Setup OTA/ViL Validation

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Picture: M. Holder

Validation Methodology of Radar Detection Data

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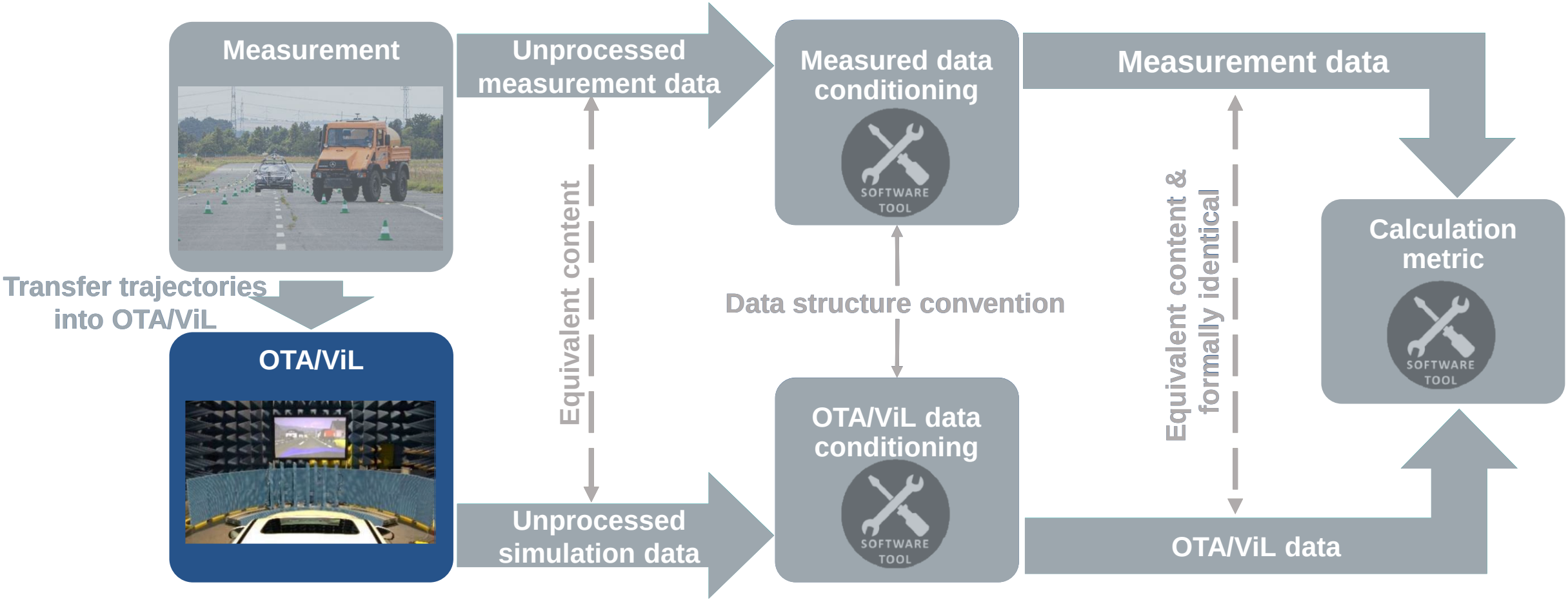

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OTA/ViL in Virtual Test and Simulation Area (VISTA)

Model (AL1)

Stimulus (AL2)

Sensor (AL3)

OTA/ViL simulator

Host PC

Target PC

Range, velocity, RCS (Ethernet)

Radar object parameters

Radar Target Simulator (RTS)

Backend

Signal: frequency, Doppler, amplitude (RF cable)

Frontend

Azimuth, elevation – Antenna (CAN bus)

Radar

Restbus signals → ego car velocity, relative position

(CAN bus)

← Object list range, velocity, RCS, azimuth

AL – (Data) Abstraction layer

Validation Methodology of Radar Detection Data

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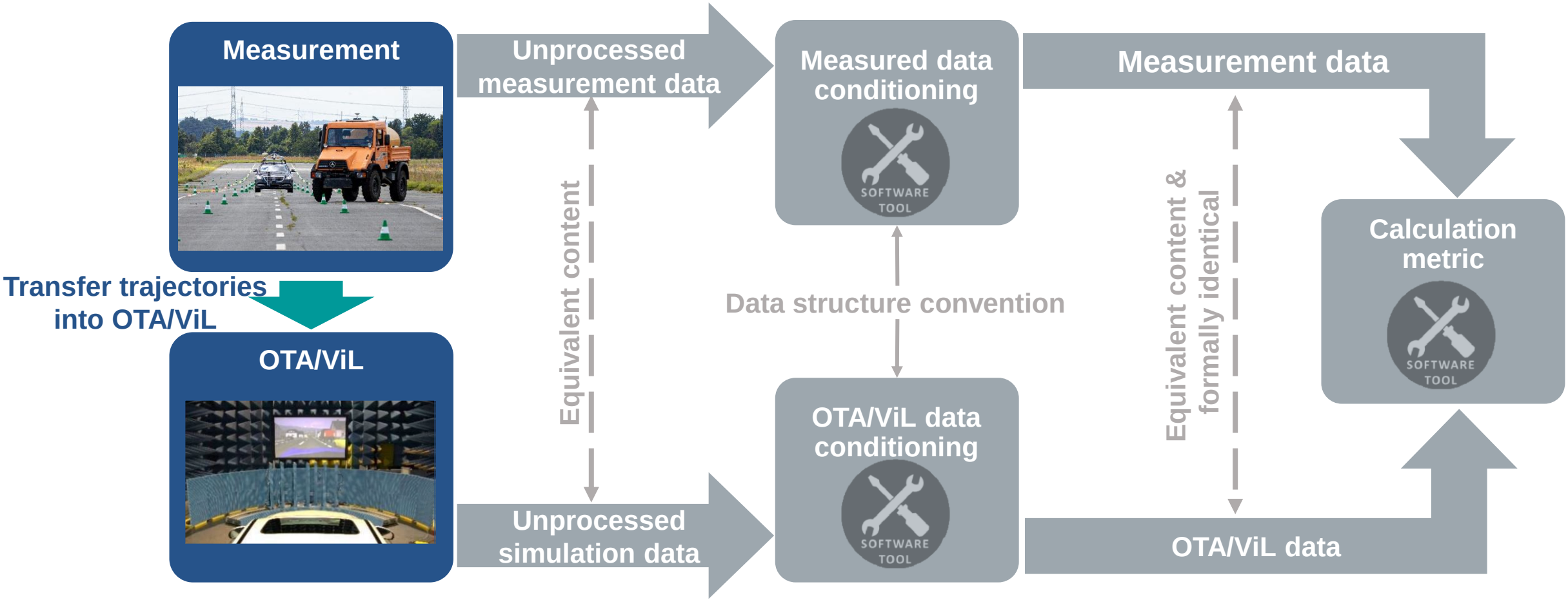

Adapted source: M. Viehof: *Objektive Qualitätsbewertung von Fahrdynamiksimulationen durch statistische Validierung*, PhD Thesis, TU Darmstadt, Darmstadt, 2018

Resimulate Slalom Drive in OTA/ViL Testbed

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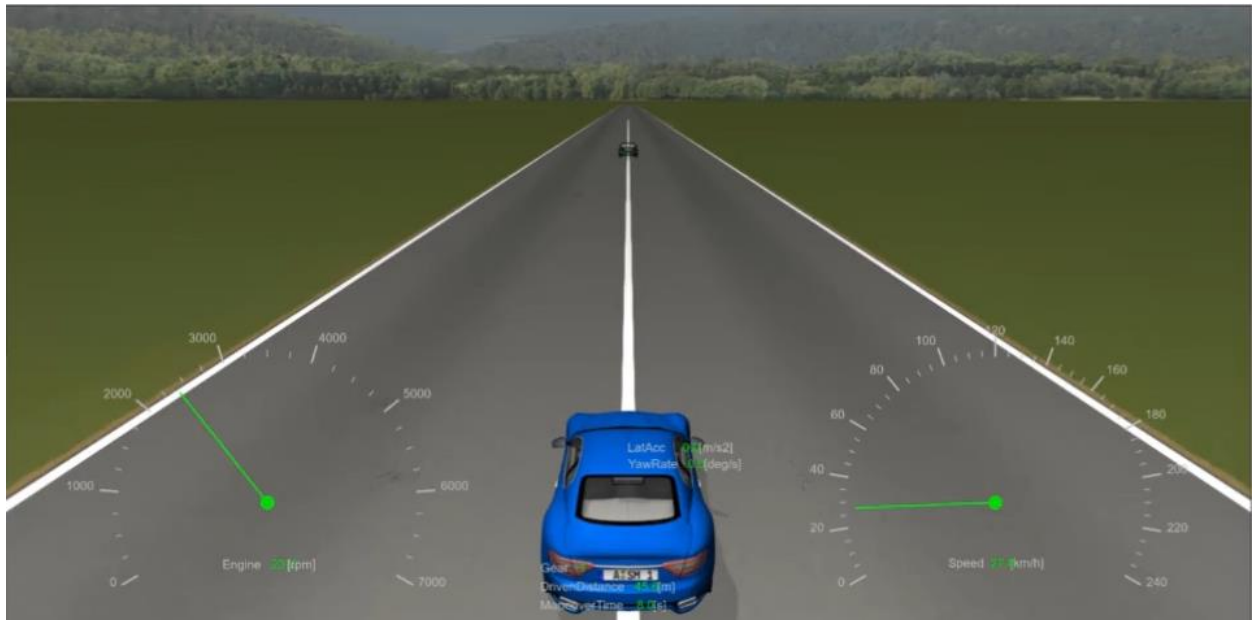

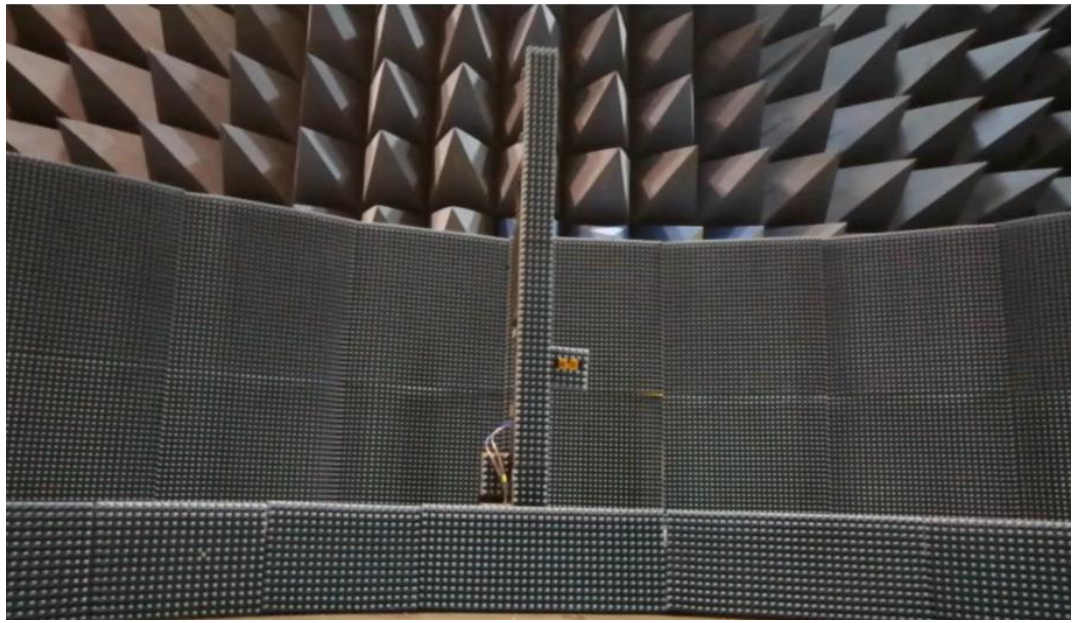

Validation Methodology of Radar Detection Data

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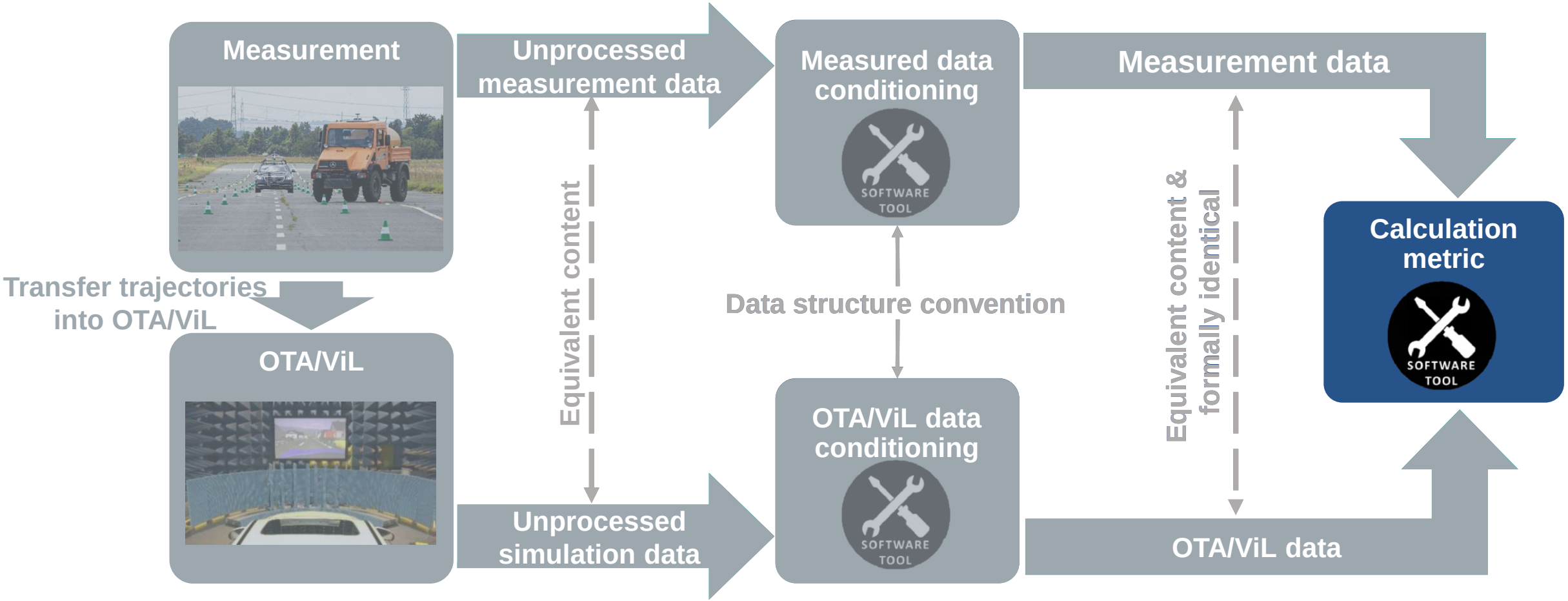

Adapted source: M. Viehof: *Objektive Qualitätsbewertung von Fahrdynamiksimulationen durch statistische Validierung*, PhD Thesis, TU Darmstadt, Darmstadt, 2018

Empirical Probability Density Functions (ePDF)

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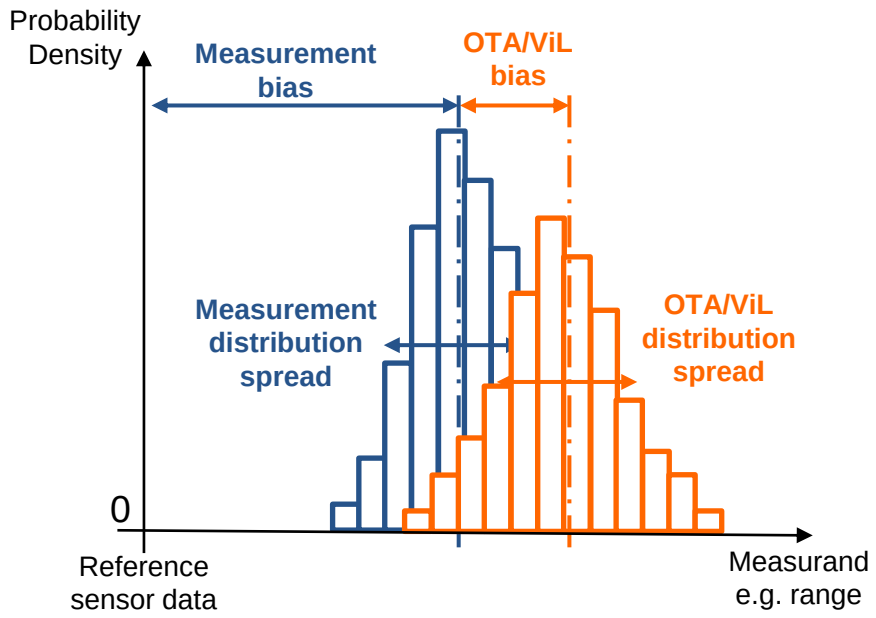
ePDF



How can we compare the bias between the measured and OTA/ViL data?

How can we determine the deviation in the distribution spread between measurement and OTA/ViL?

Empirical Cumulative Distribution Function (eCDF)

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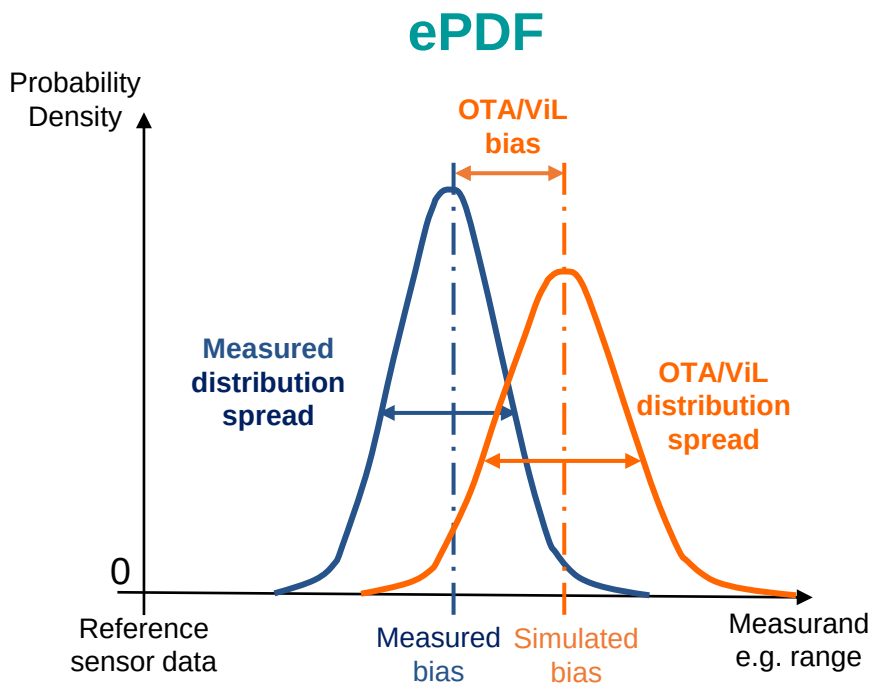

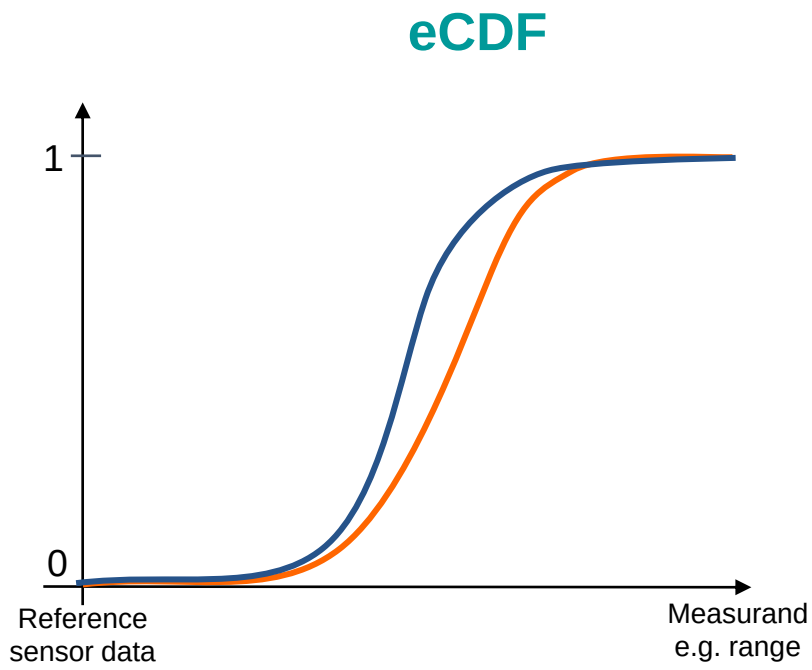

Determine Model Bias

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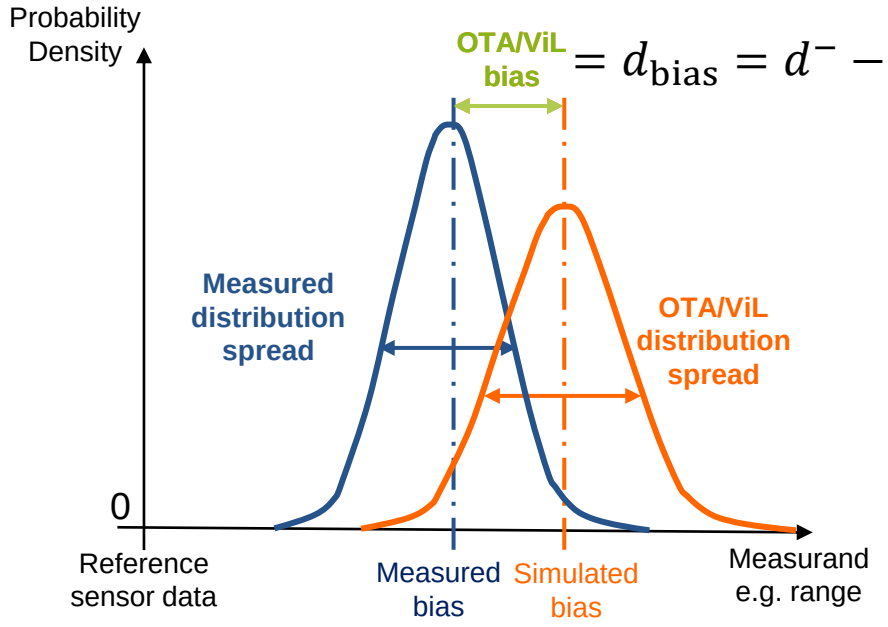
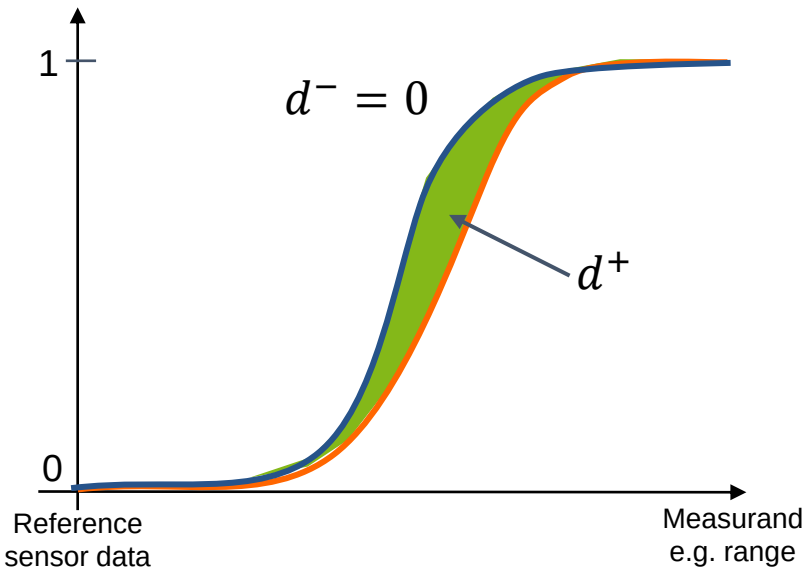
ePDF



eCDF



Determine Distribution Spread

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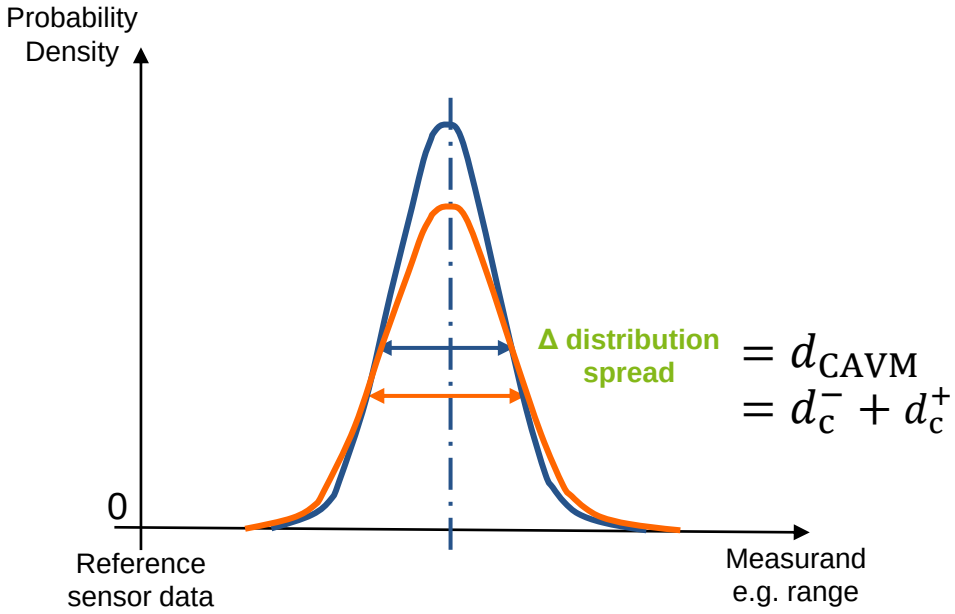
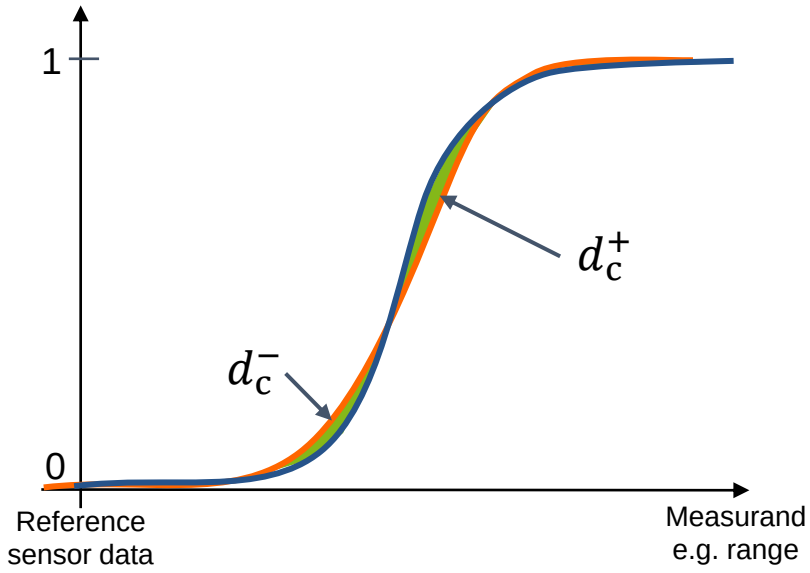


eCDF



Double Validation Metric (DVM) Map

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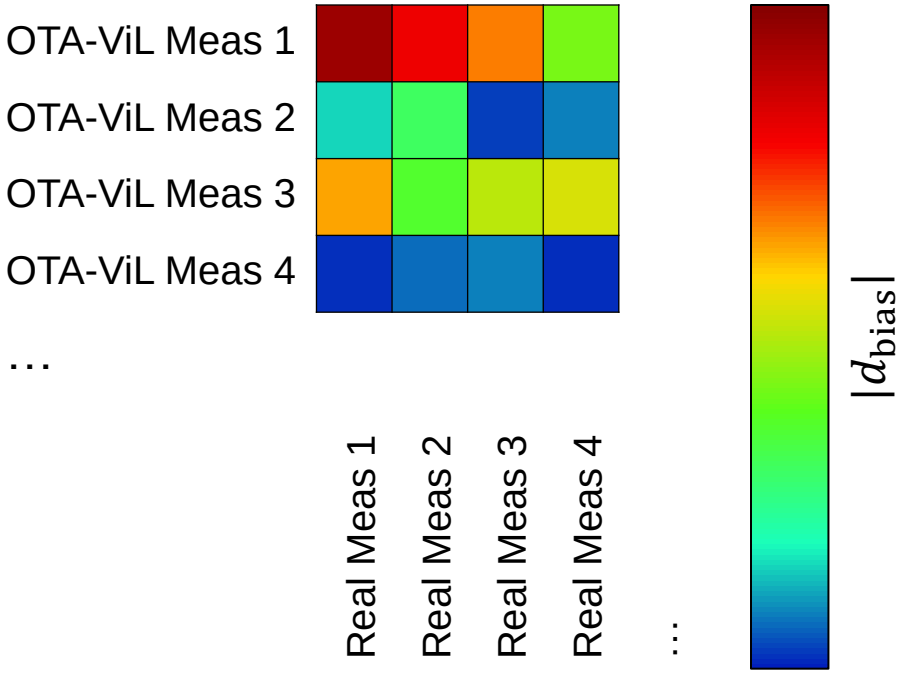
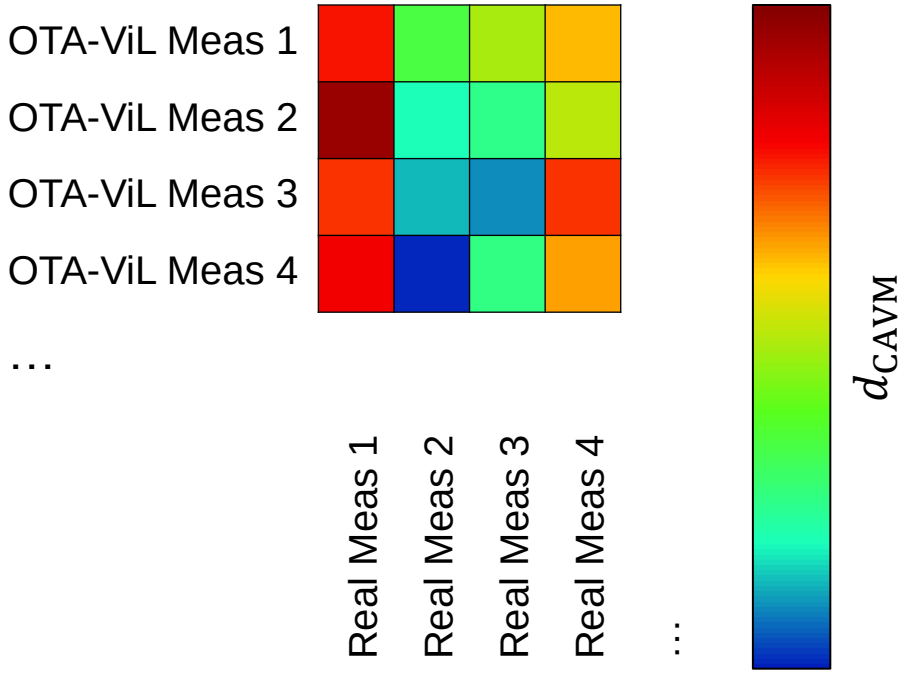
eCDF all OTA/ViL and proving ground measurements

Calculate $|d_{\text{bias}}|$ and d_{CAVM}

Create DVM Map





Outline

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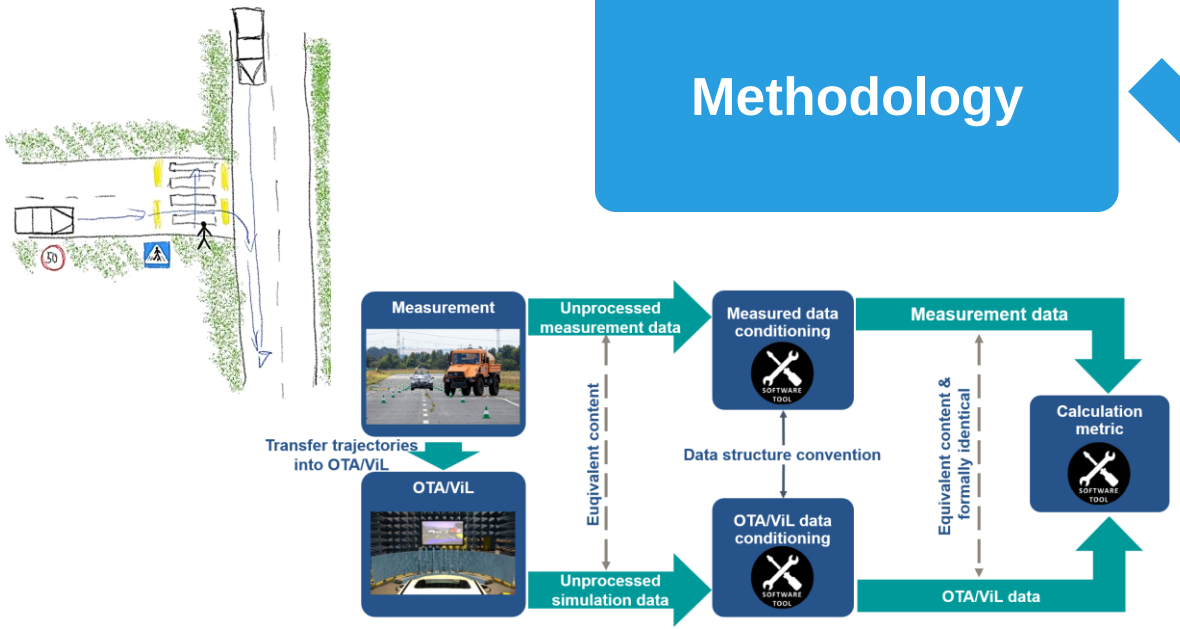
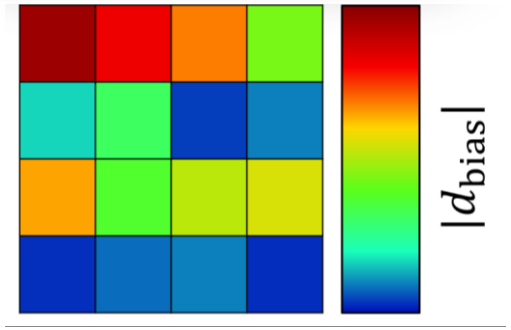
Methodology



Experimental setup



Evaluation

DVM Map Detection Data Range

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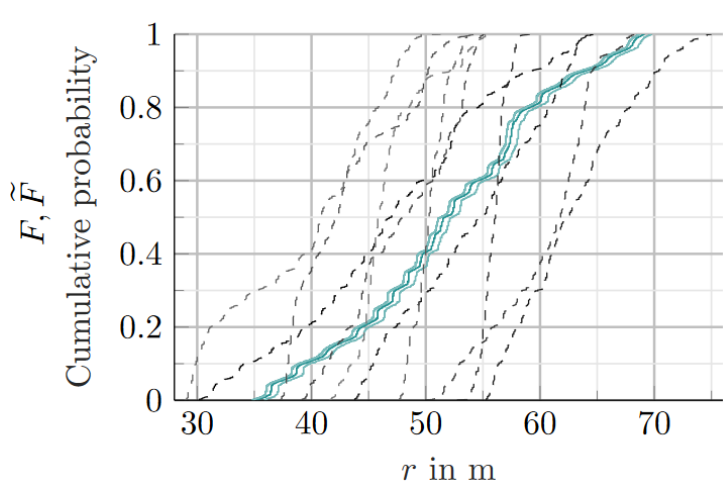

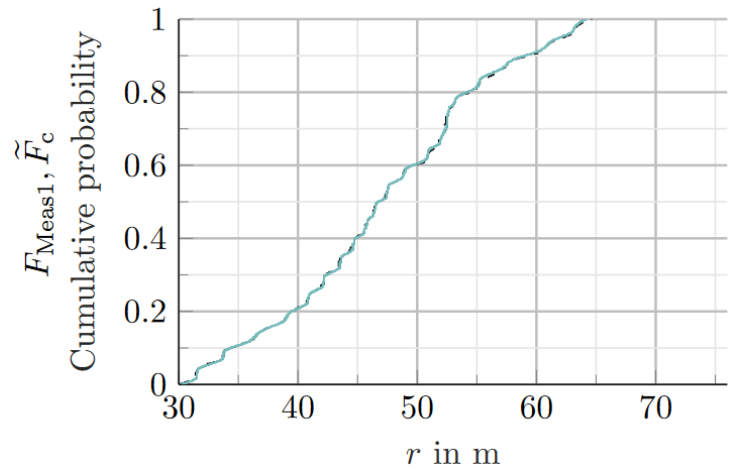

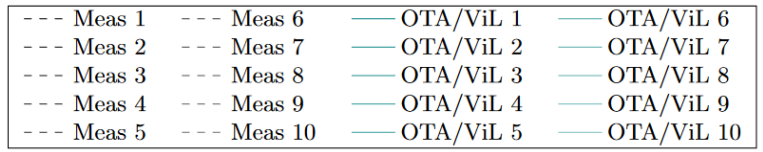

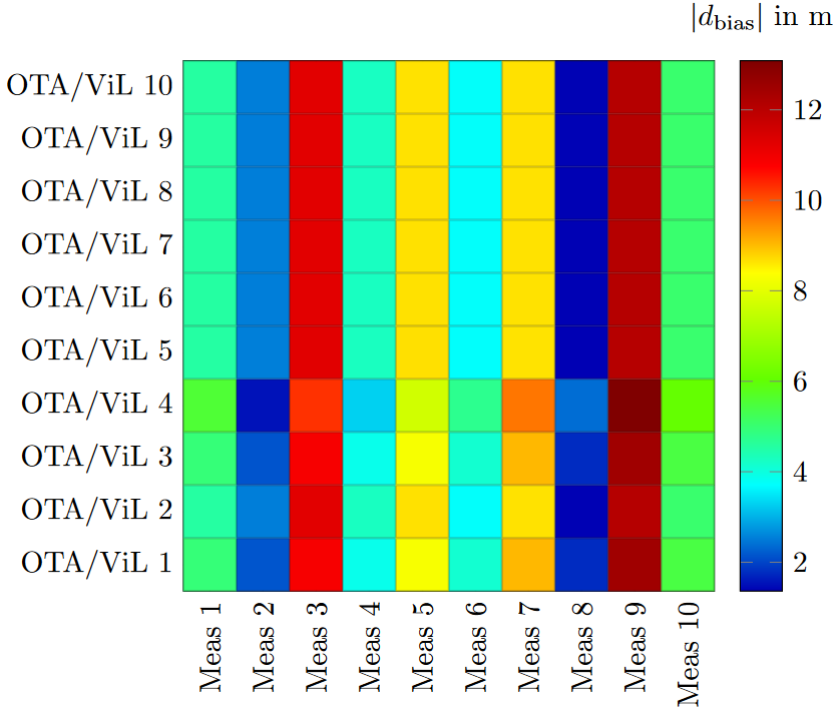

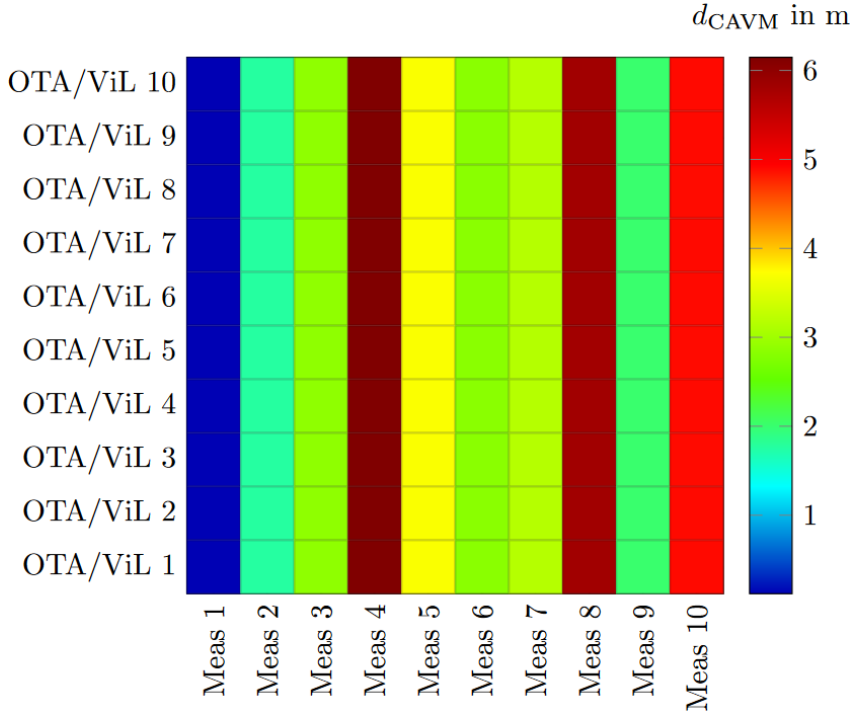

DVM Map Detection Data Azimuth

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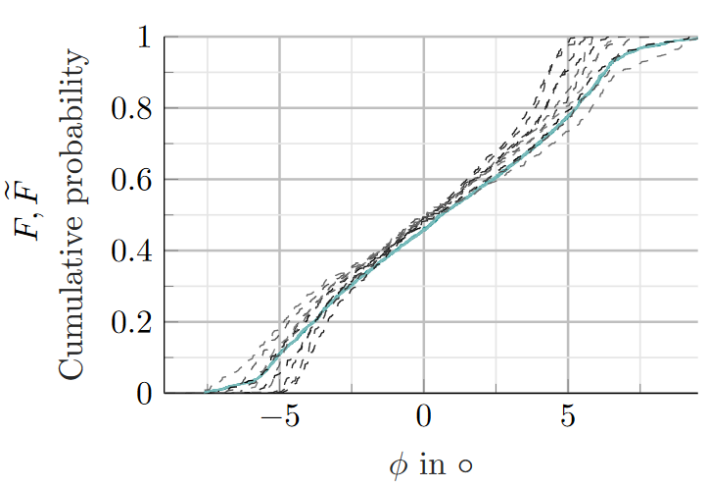

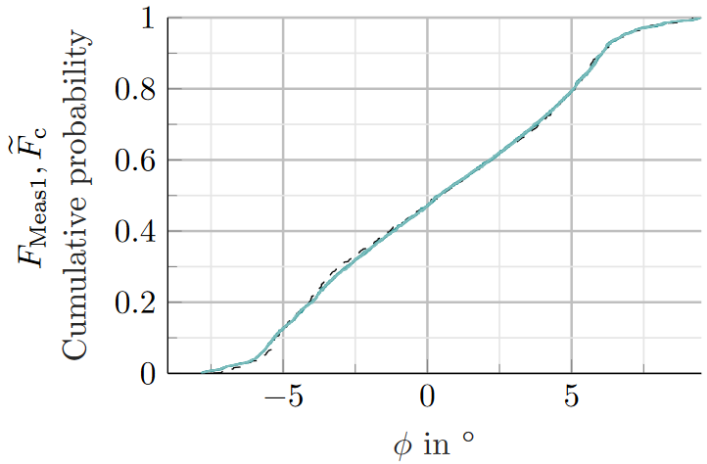

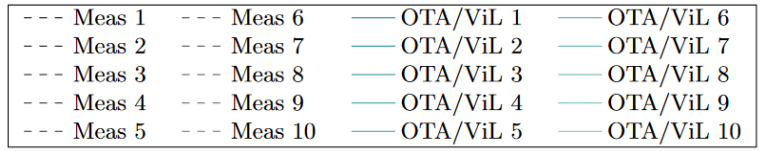

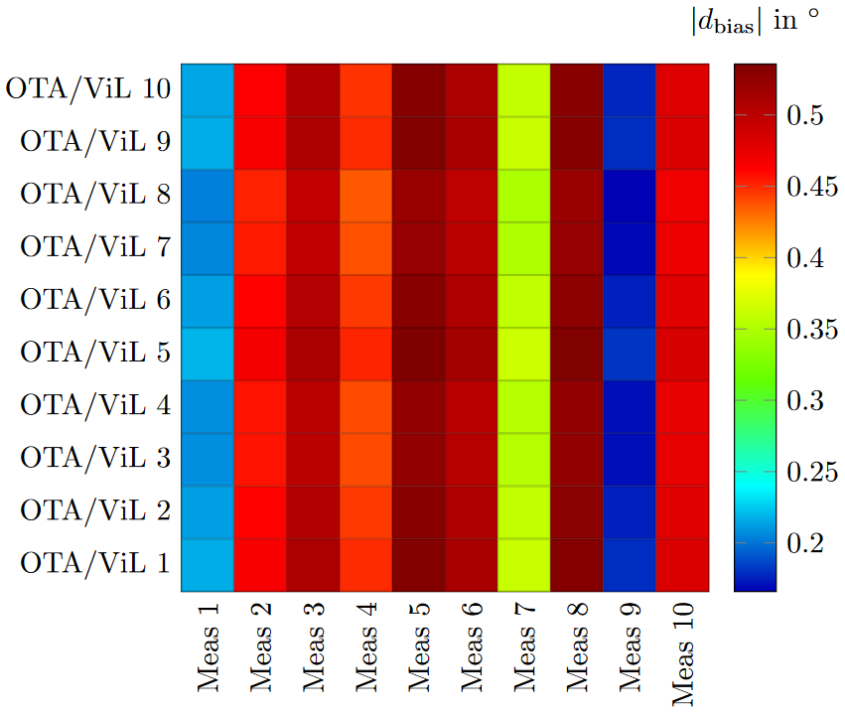

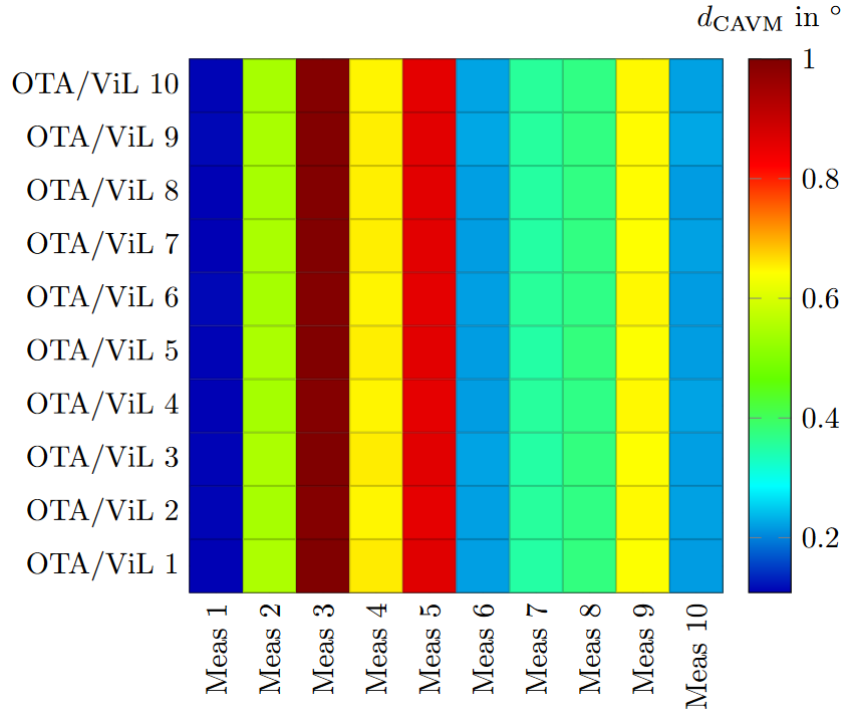

DVM Map Detection Data RCS

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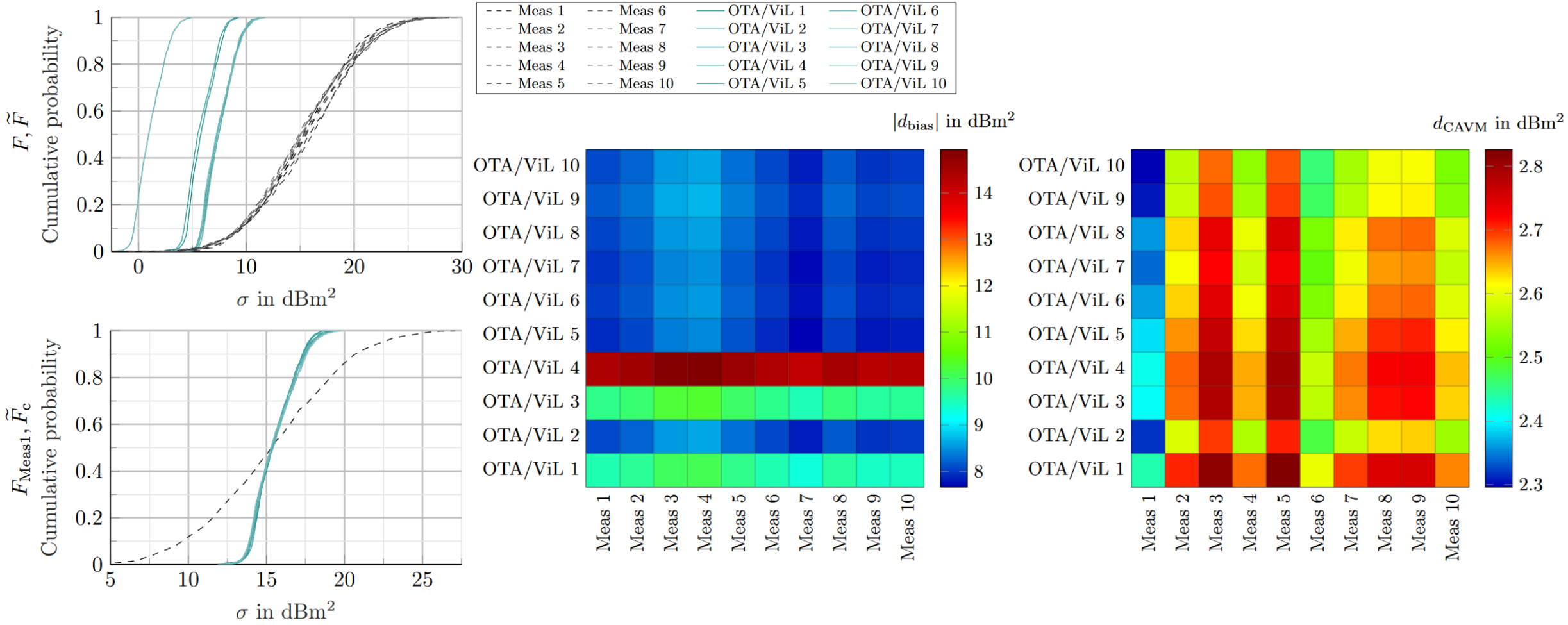

DVM Map Detection Data Velocity

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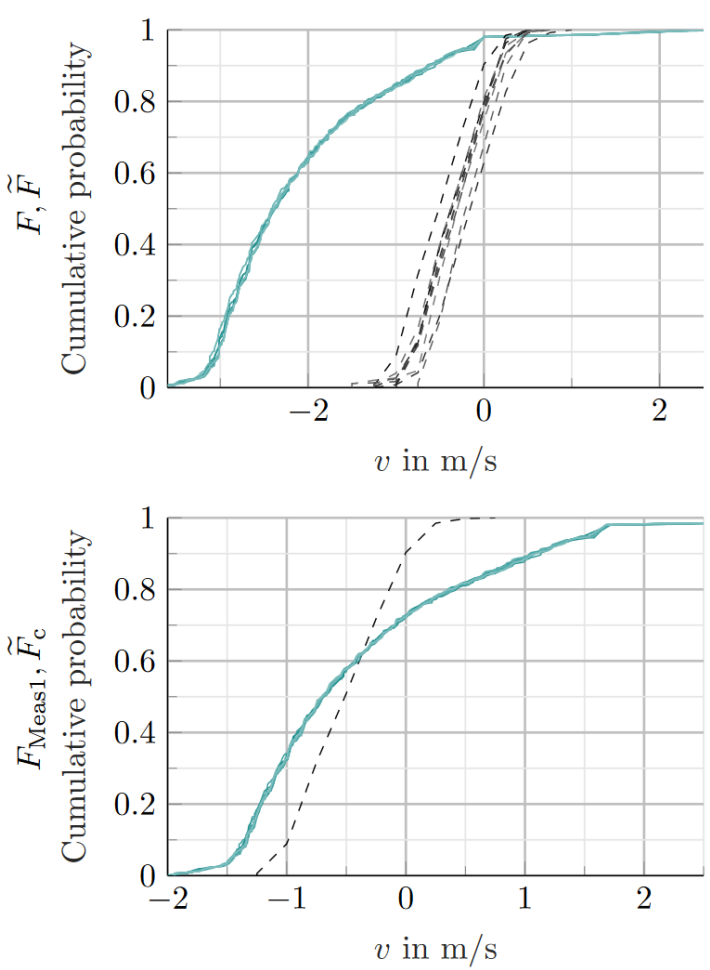

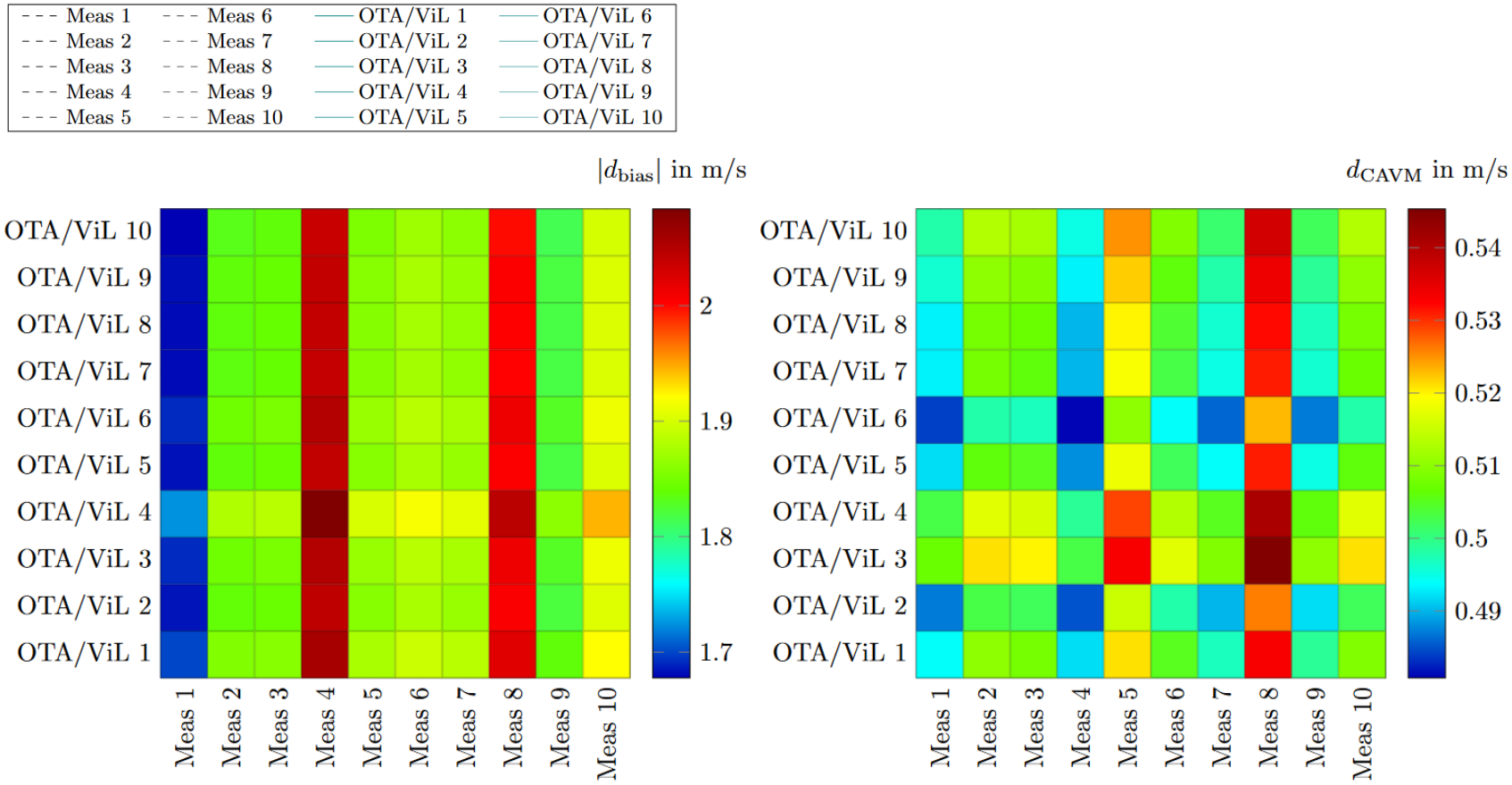

Summary

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How can we compare the bias and distribution spread between the measured and OTA/ViL data?

→ **DVM Map enables the unit conform comparison of measured and OTA/ViL data**

What is the effect of the slalom drive onto the RCS σ and position distribution of the radar detection data in an OTA/ViL testbed?

→ **OTA/ViL testbed shows high validity for RCS and azimuth**

→ **Lower validity in case of velocity and range**

→ **Temporal information get lost**

How do we objectively measure the OTA/ViL capabilities based on measurements?

→ **DVM Map is objective metric with high interpretability**

Conclusion & Outlook

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Conclusion

- DVM Map enables comparison of proving ground measurement and OTA/ViL data
- Valuable information about realism gap
- Interpretability given by unit conformity

Outlook

- Application on measurement data with reference data uncertainties
- Comparison of different slalom periods