KI ABSICHERUNG

Safe AI for Automated Driving

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Ontology-based data structuring, usage and testing in KI Absicherung

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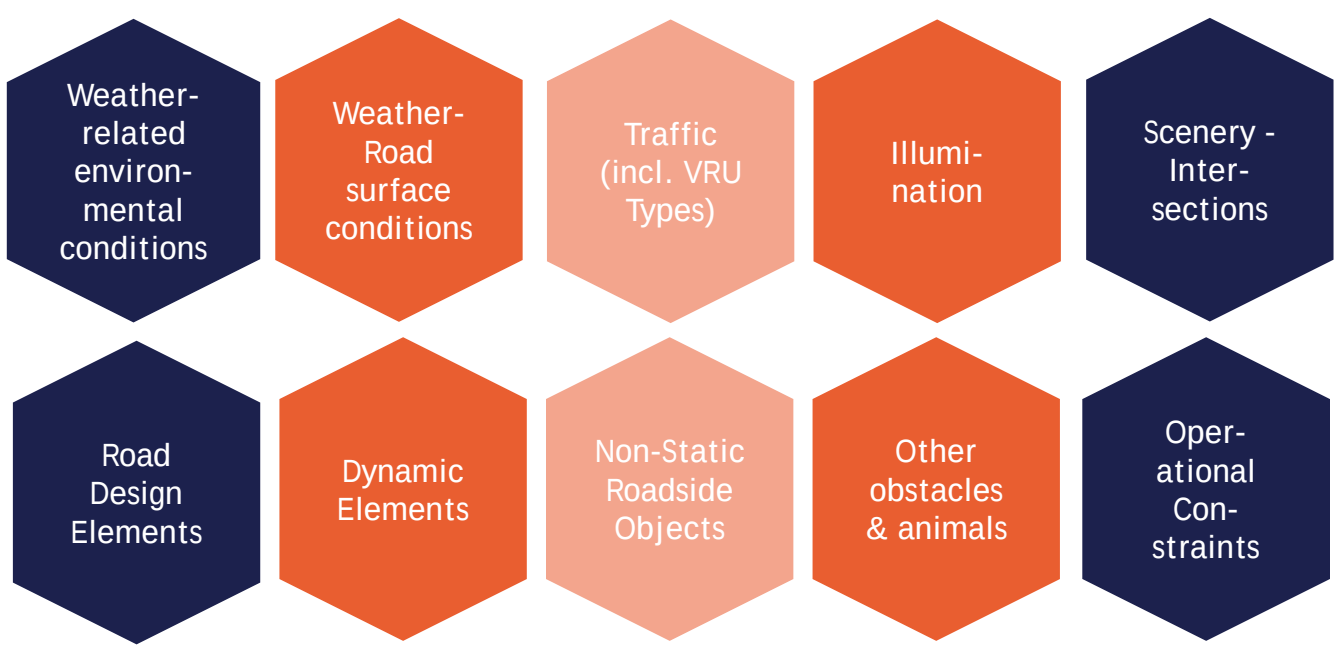
Description language and ontology development

Operational design domain (ODD)

- An ODD describes / specifies operating conditions under which a given driving automation system or feature is specifically designed to function […]
  - Taxonomy and Definitions for Terms Related to Driving Automation Systems (examples):



Level of detail?

Description language

Target:
DNN-(detection) capability to cover ODD

A description language & data input space modeling is needed to…

Complexity of language

Be able to describe / specify operating conditions (and edges of ODD*) as of PAS 1883:2020 and others

Systematically capture important knowledge and describe the (expected) key input space dimensions and their possible variations having an influence on the functional performance of a DNN-based function (→ Zwicky Boxes & Ontology)

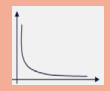
Perform training and assurance data coverage estimations for data driven AI-based systems

Describe Corner cases / rare critical situations to be considered in training / test data sets

For synthetic perception data production & meta-data: describe data dimensions that should be variated & incrementally generate new data by analyzing coverage and generating missing combinations

DNN-specific Safety Concerns (examples)

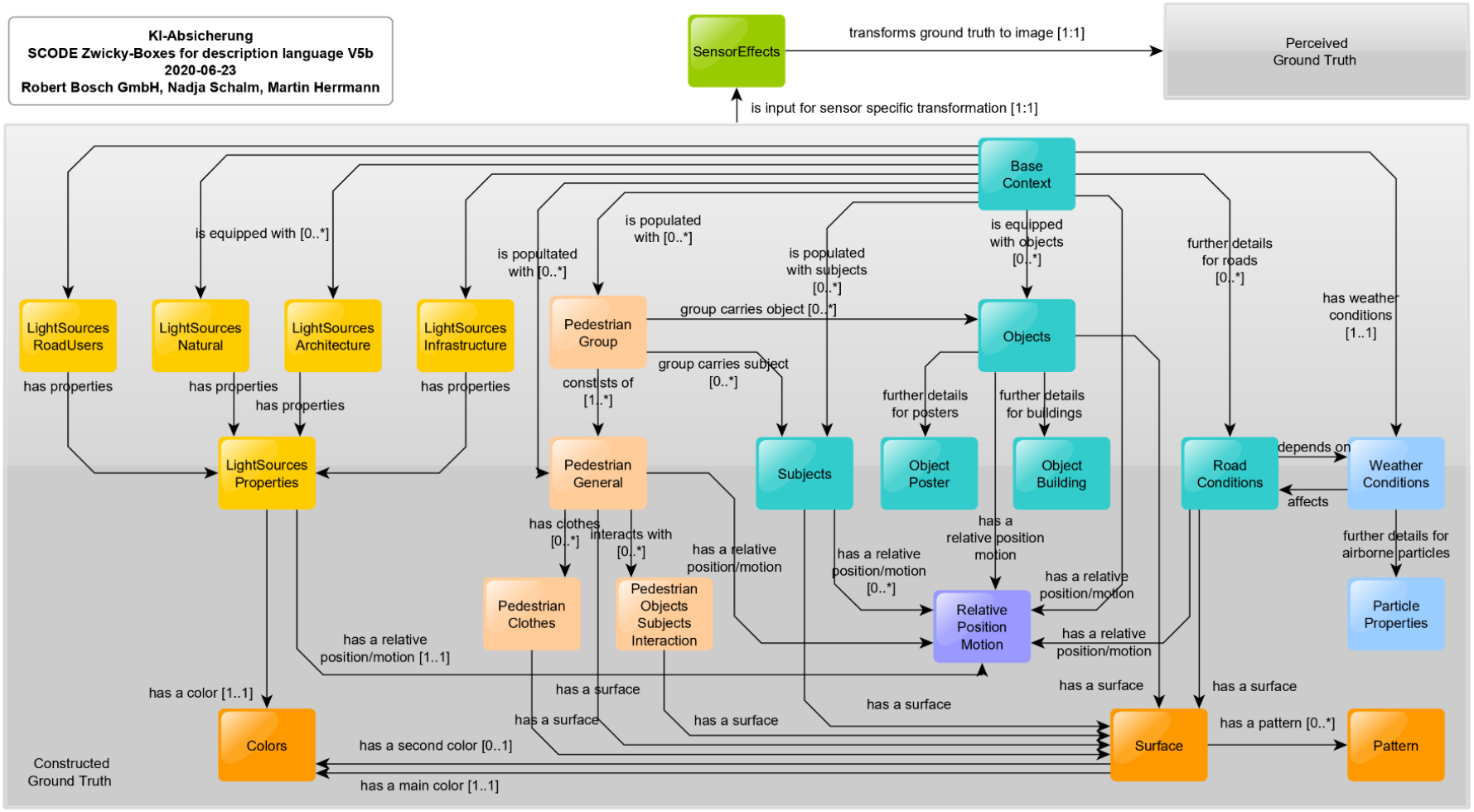
Data distribution is not a good approximation to target domain



Unknown behavior in rare safety-critical situations

Based on: O. Willers, S. Sudholt, S. Raafatnia, S. Abrecht: Safety Concerns and Mitigation Approaches Regarding the Use of Deep Learning in Safety-Critical Perception Tasks

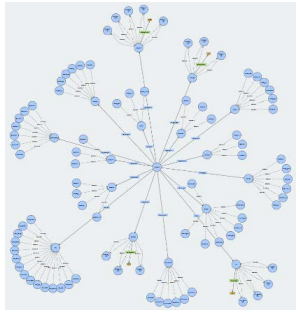
High Level view of Ontology / Domain model derived from SCODE Zwicky-Boxes



Quelle: Bosch

Data representations of the data input space aligned to ontology

Ontology Graph (Relations)



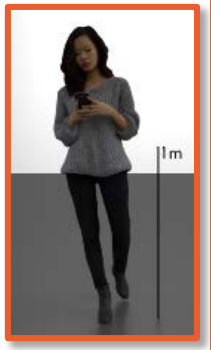
Visualization of KI Absicherung pedestrian sub ontology

Representations of variations

Daytime	morning	day	evening	night	
Haze/Fog	no		yes		
Street condition	dry	wet	icy	snow	broken
Sky	cloudy	no	clear		
Rain	no		yes		
Reflection on road	no		yes		
Shadow on road	no		yes		
VRU type	adult		child		
VRU pose	pedestrian	jogger	cyclist		
VRU contrast to BG	low		high		

Zwicky Box – Discretized variations of important dimensions (Bosch)

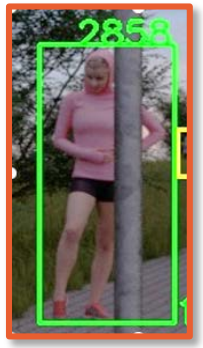
Asset & Object descriptions for data analytics



Source: BIT-TS

Pedestrian:Age "adult"
Pedestrian:BodyHeight "160cm-200cm"
Pedestrian:BodyShape "thin"
Pedestrian:BodyType "hourglass"
Pedestrian:FaceShape "oval"
Pedestrian:Gender "female"
Pedestrian:HairColor "black"
Pedestrian:HairLength "long"
Pedestrian:HairStyle "other"
Pedestrian:Pigmentation "medium"
Pedestrian:Pose "walking"
Pedestrian:SkinModification "no"
Pedestrian:SpecialHandicap "no"

Object GT Annotations for DNN-Training & Testing



Source: BIT-TS

Height = 55 px
Width = 10 px
Occlusion_level: 80%
Occluded_body_part: arm
Occluder: lamp
Within_breaking_distance_30kph: true

Systematic Combination of variations

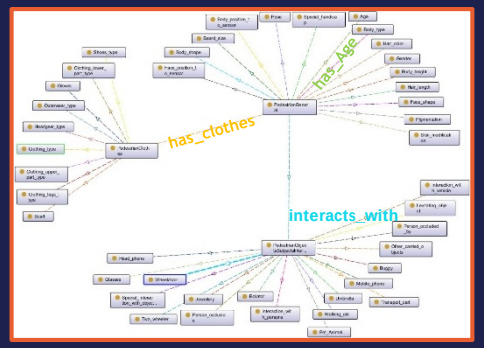
Dimension	Person1	Person2	Person3	…
Age	Child	Teenager	Adult	
Gender	Male	Female	Male	
Body height	80-120 cm	120-160 cm	160-200 cm	
Pose	Running	Lying	Walking	
Pedestrian Location	Middle of street	Left side walk	Right side walk	
…	…	…	…	

Systematically identify and describe the (known / expected) key input space dimensions and their possible variations & combinations having an influence on the functional performance of a DNN-based function

*) GT = Ground Truth

Structured Incremental dataset generation to boost data coverage (Vision)

Domain model / data input space

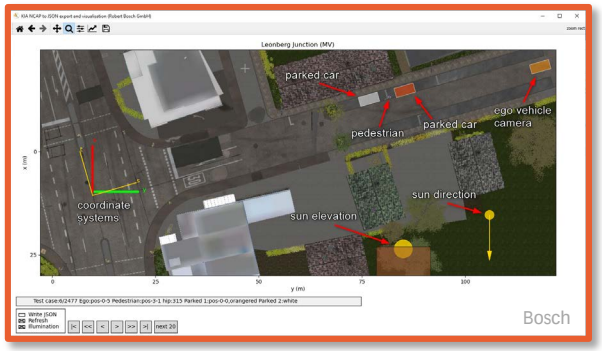


Known Performance Limitations
(expert know-how)

- Person occlusions
- Low contrast: similar color to background
- Uncommon person locations
- Uncommon poses

Possible Variations based on Ontology

Data Request tool



JSON

Synth. Data production

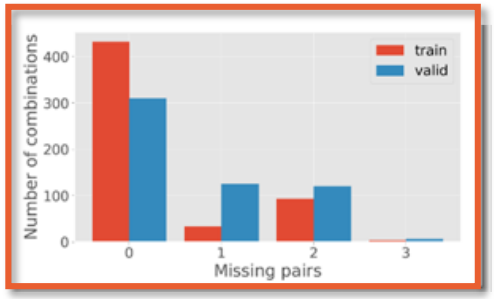
Annotations & Meta data

Data Coverage Analysis

Dimension	Person1	Person2	Person3
Age	Child	Teenager	Adult
Gender	Male	Female	Male
Body height	80-120cm	120-160cm	160-200 cm
Pose	Running	Lying	Walking
Pedestrian Location	Middle of street	Left side walk	Right side walk
...	...	...	...

Optimized Combinatorial Testing (example)

Missing Combinations



Constrained test-space

Incremental dataset generation

Test method result as input to Assurance Case (to be combined with other data related evidences)

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NCAP inspired test data production process

ML-Lifecycle-Validation data

ML LIFECYCLE

- ML-Data
- Model design
- Pre-Processing
- Training
- Post-Processing
- **Test/ V&V incl. Daten**
- Monitoring
- Maintenance

Relations to the safety assurance with NCAP like scenarios

Discretisation of dimensions

Combine the dimensions 3-Wise

Data production

Analysis:
- Critical frames with insufficient detection performance
- Stability of detection
- Uncertainty evaluation

Extrapolation to safety goal

All relevant pedestrians are detected in the ODD

Data request JSON

Data production

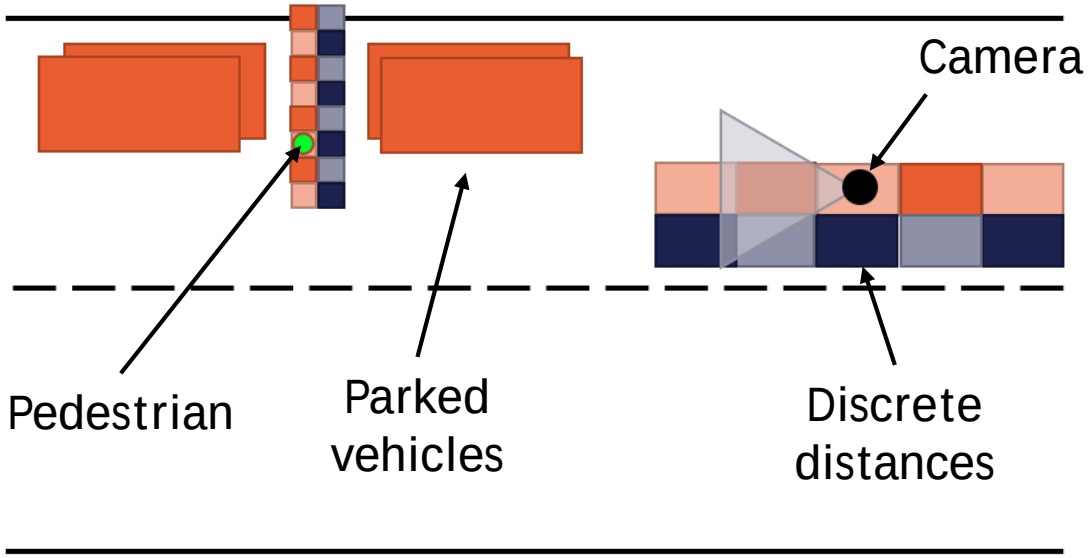
Raw data

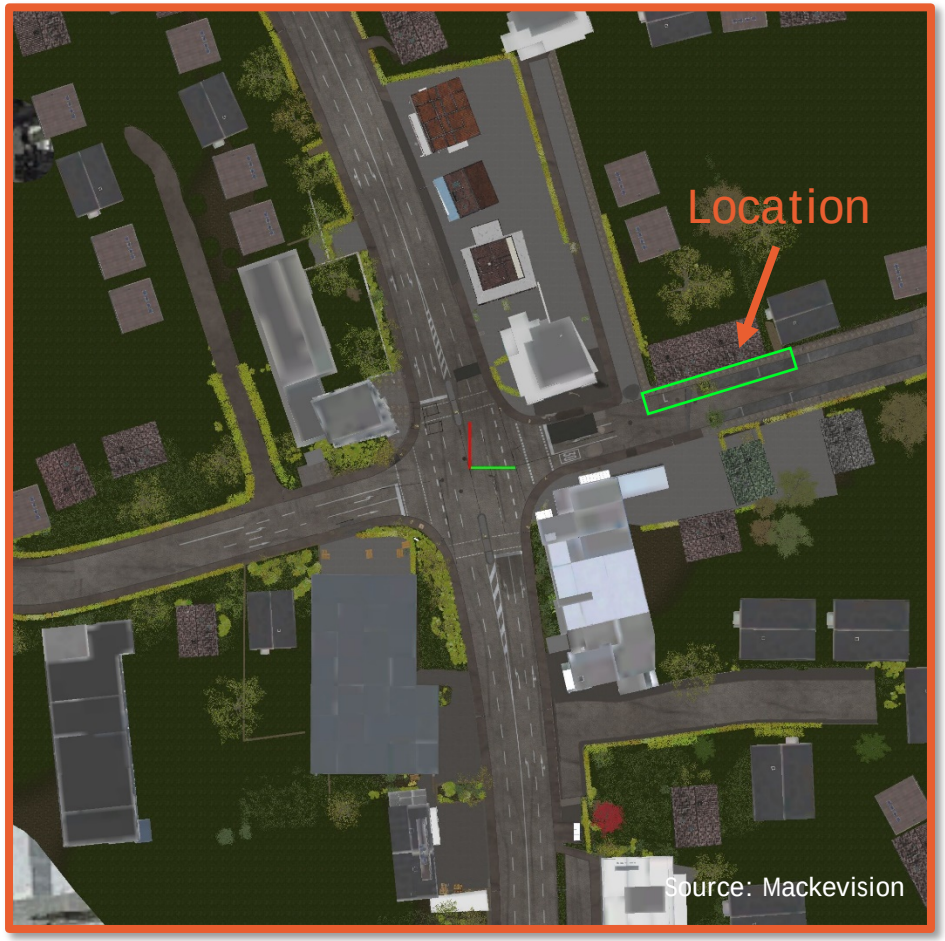
DS1	Information lossy data
DS2	Noise generation
DS3	Image corruptions
DS4	Adverserial attacks
DSx	...

Modified data

Definition of base scenario and location on base context

Story
A pedestrian is approaching the ego vehicle between two parking cars under different environment conditions





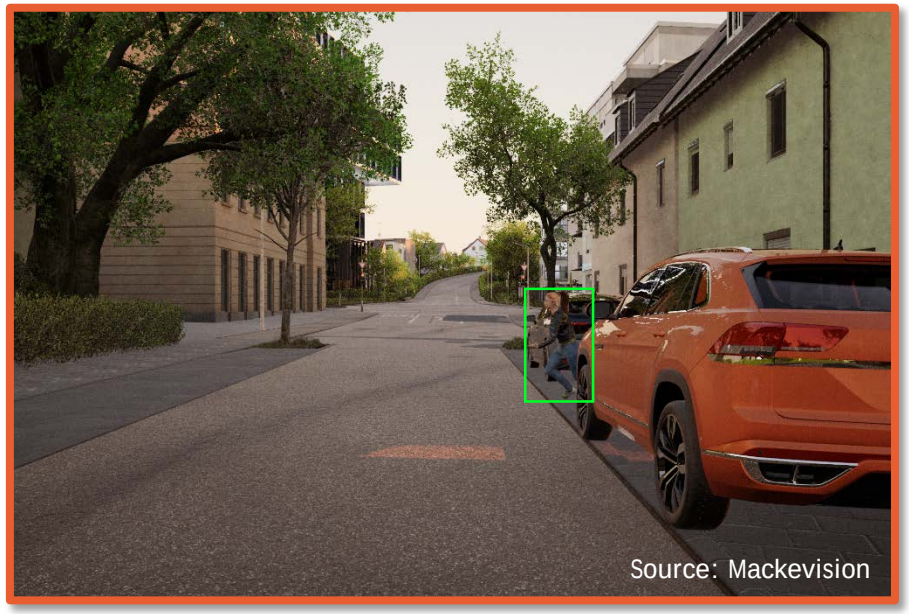
Discretization of dimensions in “Zwicky Boxes”

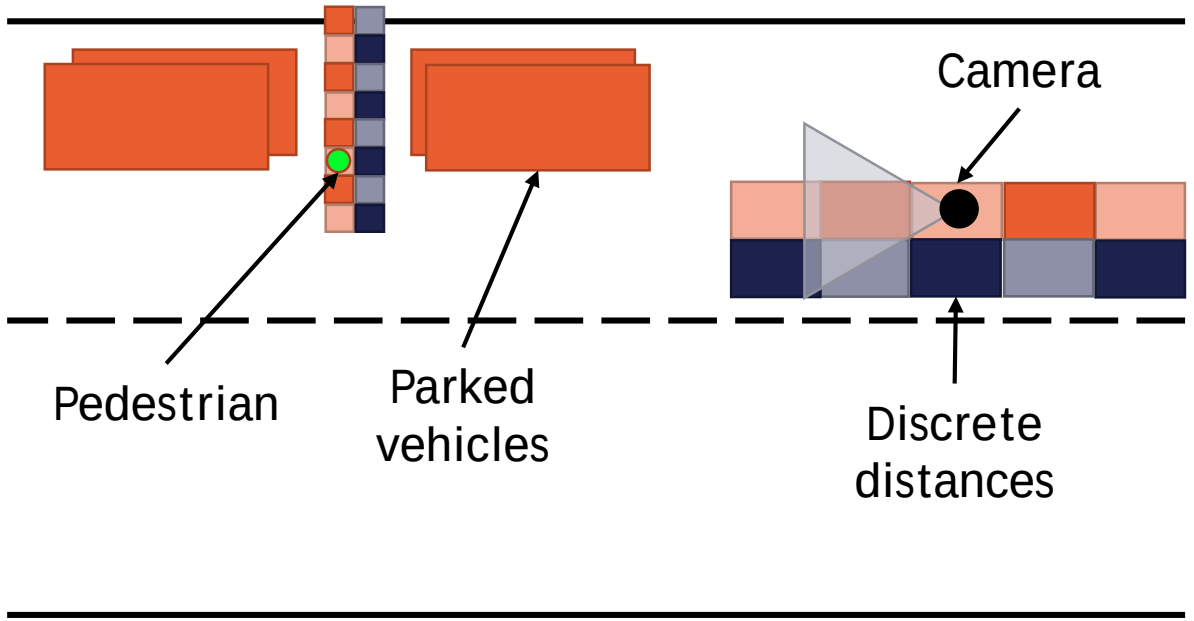
Ego XY position	pos-0-0	pos-0-1	pos-0-2	pos-0-3	pos-0-4	pos-0-5	pos-1-0	pos-1-1	pos-1-2	pos-1-3	pos-1-4	pos-1-5						
Pedestrian XY position	pos-0-0	pos-1-0	pos-2-0	pos-3-0	pos-4-0	pos-5-0	pos-6-0	pos-7-0	pos-0-1	pos-1-1	pos-2-1	pos-3-1	pos-4-1	pos-5-1	pos-6-1	pos-7-1		
Pedestrian pose	pose01				pose02				pose03				pose04				pose05	
Pedestrian asset	A1		A2		A3		A4		A5		A6		A7		A8		A9	A10
Pedestrian hip direction	d0		d45		d90		d135		d180		d225		d270		d315			
Parked vehicle 1 type	BMW1			BMW2			BMW7I			VW ID.3			VW Golf 8			VW Atlas		
Parked vehicle 1 XY position	pos-0-0		pos-0-1		pos-0-2		pos-1-0		pos-1-1		pos-1-2		pos-2-0		pos-2-1		pos-2-2	
Parked vehicle 1 color	BMW Black	BMW Cerium grey	BMW Melbourne red	BMW Mineral grey	BMW Misano blue	BMW Sao Paolo yellow	BMW Snapper Rocks blue	BMW Sunset orange	BMW White	VW Gletscher Weiss	VW Mangangrau	VW Mekana Turquoise	VW Mondsteingrau	VW Scale Silver	VW Stonewashed Blue	VW Energetic Orange	VW Deep Black	VW Delfingrau	VW Kings Red
Parked vehicle 2 type	BMW1			BMW2			BMW7I			VW ID.3			VW Golf 8			VW Atlas		
Parked vehicle 2 color	BMW Black	BMW Cerium grey	BMW Melbourne red	BMW Mineral grey	BMW Misano blue	BMW Sao Paolo yellow	BMW Snapper Rocks blue	BMW Sunset orange	BMW White	VW Gletscher Weiss	VW Mangangrau	VW Mekana Turquoise	VW Mondsteingrau	VW Scale Silver	VW Stonewashed Blue	VW Energetic Orange	VW Deep Black	VW Delfingrau	VW Kings Red
Illumenation	direct sun								diffuse light									
Sun direction	d0		d45		d90		d135		d180		d225		d270		d315			
Sun elevation	low					medium						day						
Road surface	A				B				C				D					

Source: Bosch

- **Discretization:** The most critical dimensions are identified and discretized
- **Test coverage:** With pairwise testing it’s possible to achieve a high error coverage in traditional software testing

Data production - Example data snapshot 1

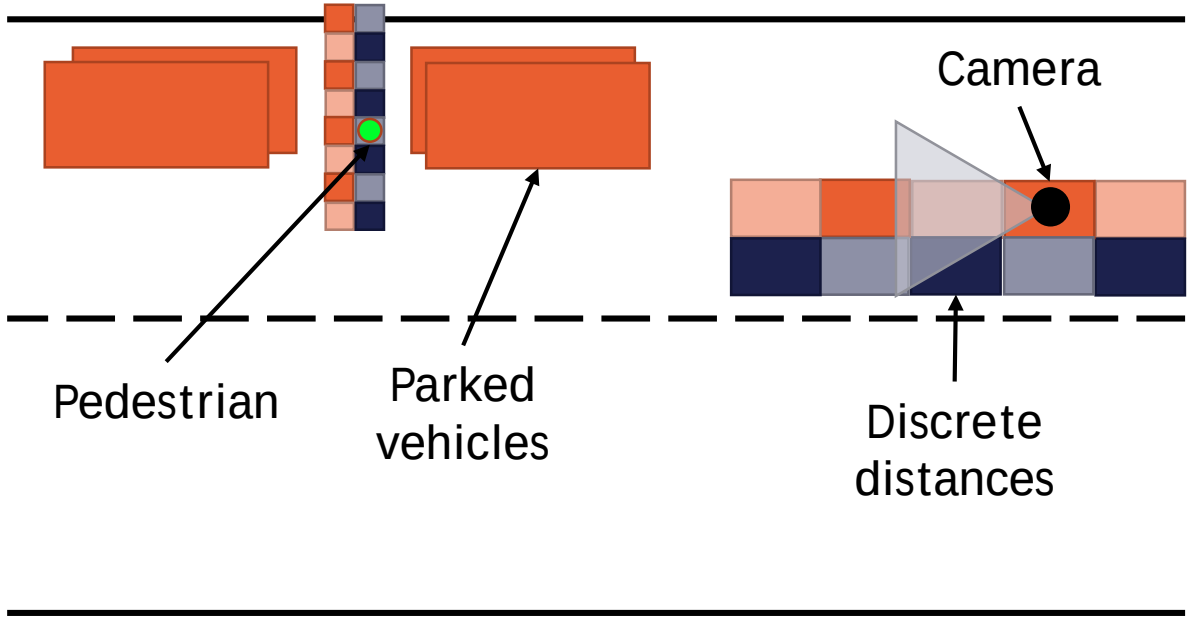




- **Safety critical:** Pedestrian has a running pose towards the camera
- The perception function shall be able to detect the pedestrian early enough without any image perturbations

- Those images are well suited as a reference for the analysis of brittleness in DNN's

Data production - Example data snapshot 1



- **Safety critical**: The legs are extended to the driving lane
- **Uncommon pose**: Pedestrian lays between two vehicles and is difficult to see

- In which combinations is the object detector **not** capable to perceive the pedestrian?

Examples for data post processing

original

fog

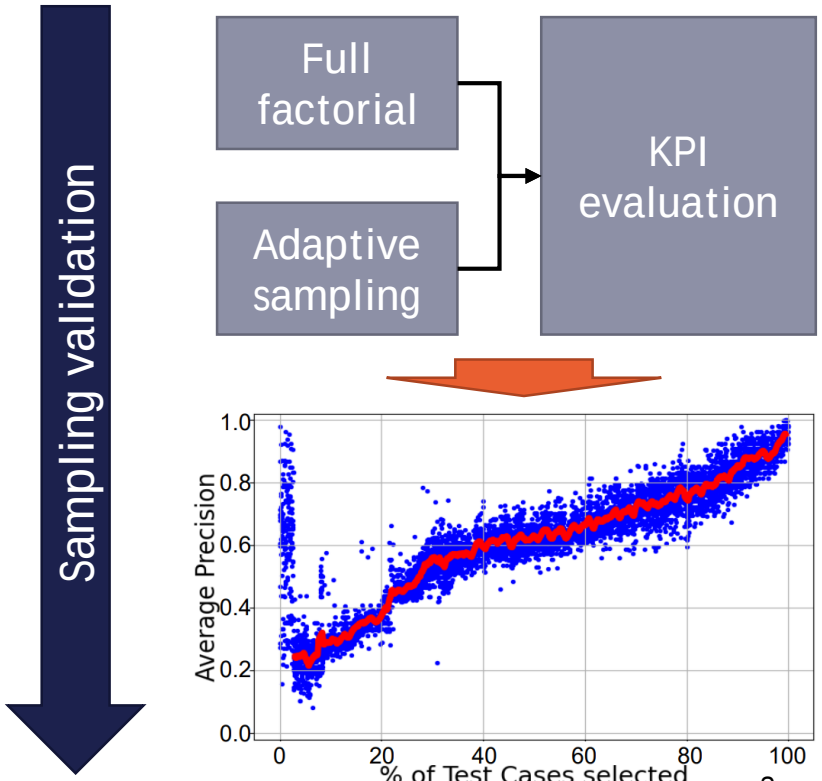
frost

brightness

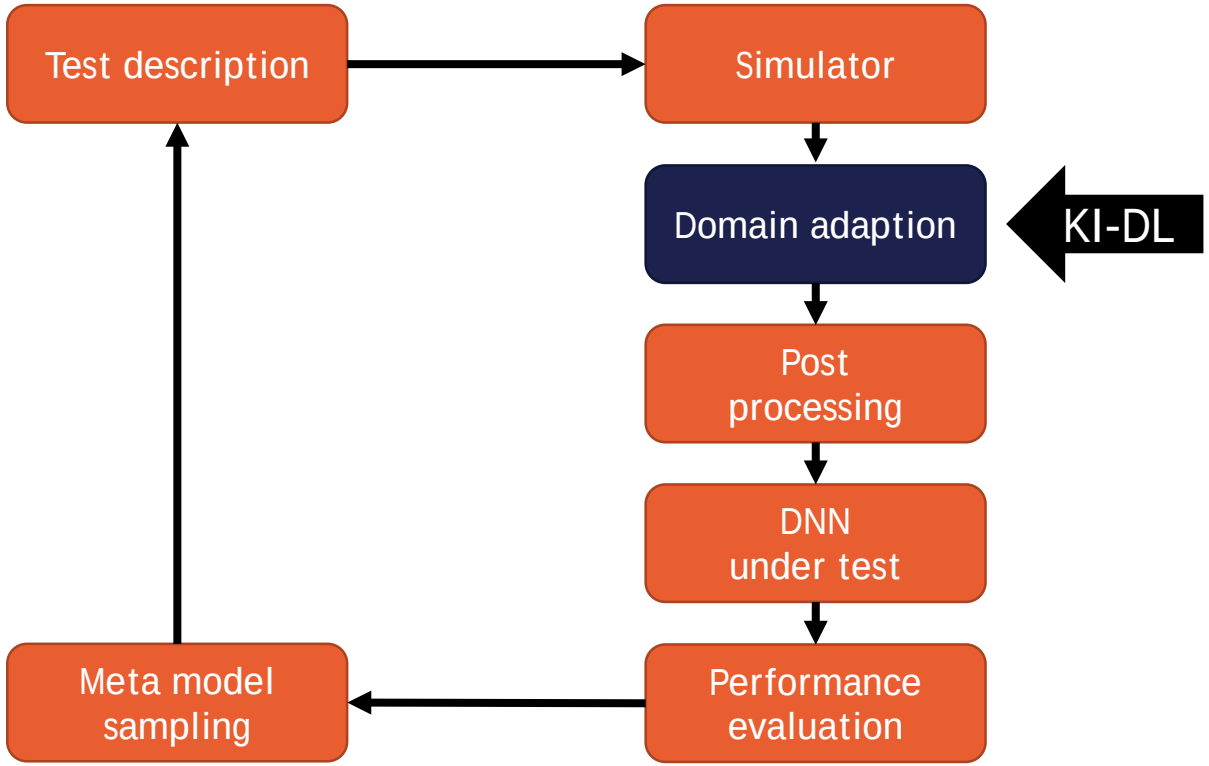
contrast

Motion blur

Test space exploration optimization



Source: ZF



The most performance critical test cases are identified early in the test exploration
"Adaptive test case selection for DNN-based perception functions"
Paper release: ISSE 2021 – 7th IEEE International Symposium on Systems Engineering (ieeeisse.org)

Synthetic video data for domain adaptation studies @ KI-Absicherung

Variation of sensor parameters

- High vs. Low resolution
- Camera opening angle (field of view)
- Height of camera over ground

Conclusion & Outlook

Conclusion

- Systematic structuring of training, test and assurance data is expected to be a crucial basis for safety assurance
- Challenging and safety critical scenes are structured based on expert knowledge
- An initial systematic coverage of test cases is provided by a combinatorial testing approach and further improved by an adaptive sampling strategy
- The “good” test cases are challenged by further augmentations and corruptions
- The newly created data set can be used for a benchmarking of DNN based perception algorithms

Proposals for KI-DL

- Embed the KI-A ontology knowledge into semi-supervised and unsupervised learning approaches from KI-DL
- Integrate domain adaption methods from KI-DL into the test space exploration pipeline