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

October 7th, 2021
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):

  Weather-related environmental conditions
  Weather-Road surface conditions
  Traffic (incl. VRU Types)
  Illumination
  Scenery - Intersections
  Road Design Elements
  Dynamic Elements
  Non-Static Roadside Objects
  Other obstacles & animals
  Operational Constraints

Level of detail?

Description language

Target: DNN-(detection) capability to cover ODD
A description language & data input space modeling is needed to...

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

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

- ~250 dimensions
- ~1000 alternatives
- Several Sub-domains

Approach:
- Review of public data sources / existing standards
- Brainstorming with experts
- Expert interviews
- Iterative refinement
- Needs to be challenged / extended by identified corner cases

Quelle: Bosch

2021-10-07 | KI-A @ KI-DL midterm event
Data representations of the data input space aligned to ontology

Ontology Graph (Relations)

Systematic Combination of variations

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Person1</th>
<th>Person2</th>
<th>Person3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Child</td>
<td>Teenager</td>
<td>Adult</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Body height</td>
<td>80-120 cm</td>
<td>120-160 cm</td>
<td>160-200 cm</td>
</tr>
<tr>
<td>Pose</td>
<td>Running</td>
<td>Lying</td>
<td>Walking</td>
</tr>
<tr>
<td>Pedestrian Location</td>
<td>Middle of street</td>
<td>Left side walk</td>
<td>Right side walk</td>
</tr>
</tbody>
</table>

Object GT Annotations for DNN-Training & Testing

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

Zwicky Box - Discretized variations of important dimensions (Bosch)

Representations of variations

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

Source: BIT-TS
Structured Incremental dataset generation to boost data coverage (Vision)

Domain model / data input space

Possible Variations based on Ontology

Data Request tool

Synth. Data production

Annotations & Meta data

Data Coverage Analysis

Known Performance Limitations
(expert know-how)
• Person occlusions
• Low contrast: similar color to background
• Uncommon person locations
• Uncommon poses

Constrained test-space

Incremental dataset generation

Missing Combinations

Optimized Combinatorial Testing (example)

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

Constrained test-space

Test method result as input to Assurance Case (to be combined with other data related evidences)
NCAP inspired test data production process
ML-Lifecycle-Validation data

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

2021-10-07 | KI-A @ KI-DL midterm event
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

Modified data

- DS1: Information lossy data
- DS2: Noise generation
- DS3: Image corruptions
- DS4: Adversarial attacks
- DSx: ...

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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”

- **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

Source: Bosch
• **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
• **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**

Source: Mackevision | Source: Mackevision + ZF | Source: Mackevision + 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

Source: Mackevision
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