PROJECT of the PEGASUS FAMILY

VERIFICATION VALIDATION METHODS

Criticality Analysis - Application

9.1 | Ontologies as a connecting and formal element for developing automated systems in complex contexts

Lukas Westhofen

Application Example

Why ontologies?

⇧ Context complexity ⇒ ⇧ Relevance ontology

Example

- Urban automated driving (as in VVM)
- Highway assistance systems
- Industrial robot in enclosed space

What is the role of ontologies?

A basis for connecting all engineering steps congruently to the open and complex context.

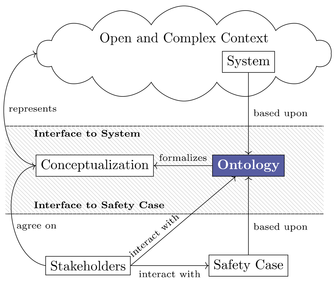


Figure 1: The role of ontologies in safety engineering (© DLR e.V.)

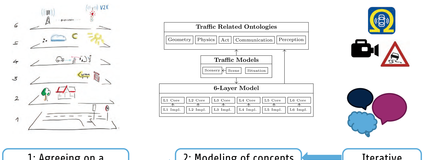
Example

Ontology-based SOTIF triggering conditions:
Occluded pedestrian during passing of *parking vehicles* on *urban 2-lane roads*

The Automotive Urban Traffic Ontology (A.U.T.O.)

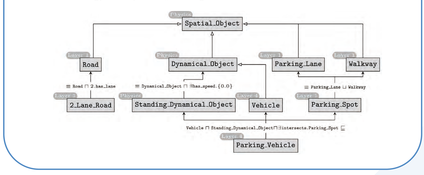
VVM exemplarily instantiated an ontology, called A.U.T.O., containing knowledge on the structure of urban traffic.

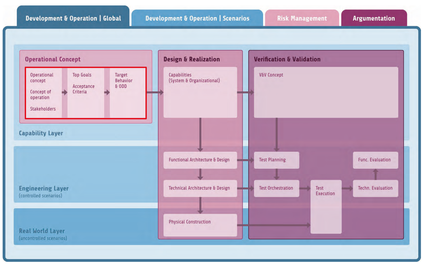
Goal: Congruency between safety case stakeholders (exemplarily limited to: criticality analysts, data format modelers, sensor experts).



Example

Ontology excerpt for „Parking vehicles on urban 2-lane roads“





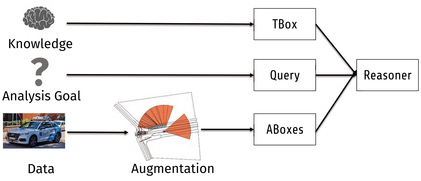
Why all the formality?

Description Logics can be used as a semantically rich data model („enhanced UML“) for logical inferences!

Example

$$(\mathcal{O}, \{\ldots, \texttt{Vehicle}(v), \exists \texttt{has\_speed}.\{0.0\}(v), \exists \texttt{intersects.Walkway}(v)\}) \models \texttt{Parking\_Vehicle}(v)$$

Data analysis: An interesting use case [2]



Results

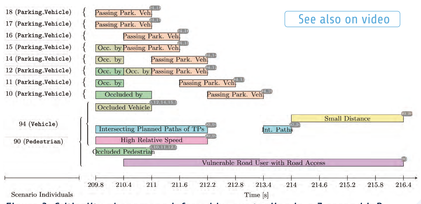


Figure 2: Criticality phenomena inferred by our tooling in a 7 second inD scenario recorded in Aachen, Germany, by the fka (© DLR e.V.)

Improvement: Handling time via temporal logics

Description Logics are incapable of handling time – a solution is offered by combining Temporal Logics with Conjunctive Queries (which we call „MTCQ“) [3].

Example

Passing of parking vehicles on urban 2-lane roads:

$$\Box\big(\exists r.\texttt{Vehicle}(x) \wedge \texttt{2\_Lane\_Road}(r) \wedge \texttt{Pedestrian}(p) \wedge \texttt{intersects}(r,x) \wedge \texttt{Parking\_Vehicle}(y)\big) \wedge \Diamond\big(\texttt{is\_in\_front\_of}(y,x) \wedge \bigcirc\big((\texttt{in\_proximity}(x,y) \wedge \texttt{is\_to\_the\_side\_of}(y,x)) \mathcal{U} \texttt{is\_behind}(y,x)\big) \wedge \Box_{[0,2]}\texttt{has\_intersecting\_path}(x,p)\big)$$

Outlook: Implement efficient algorithms for MTCQs.

References:

[1] Scholtes et al., 6-layer model for a structured description and categorization of urban traffic and environment, IEEE Access, 2021
[2] Westhofen et al., Using ontologies for the formalization and recognition of criticality for automated driving, IEEE OJITS, 2022
[3] Westhofen et al., Answering Temporal Conjunctive Queries over Description Logic Ontologies for Situation Recognition in Complex ODs, 2023

Partners

For more information contact:
lukas.westhofen@dlr.de

A project developed by the VDA Leitinitiative automated and connected driving

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag