



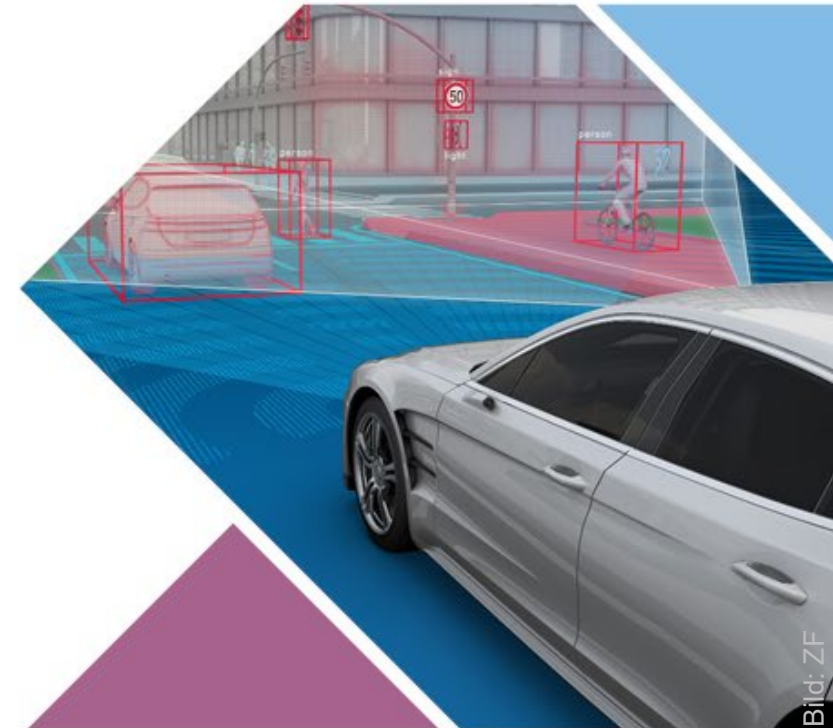
VERIFICATION
VALIDATION
METHODS

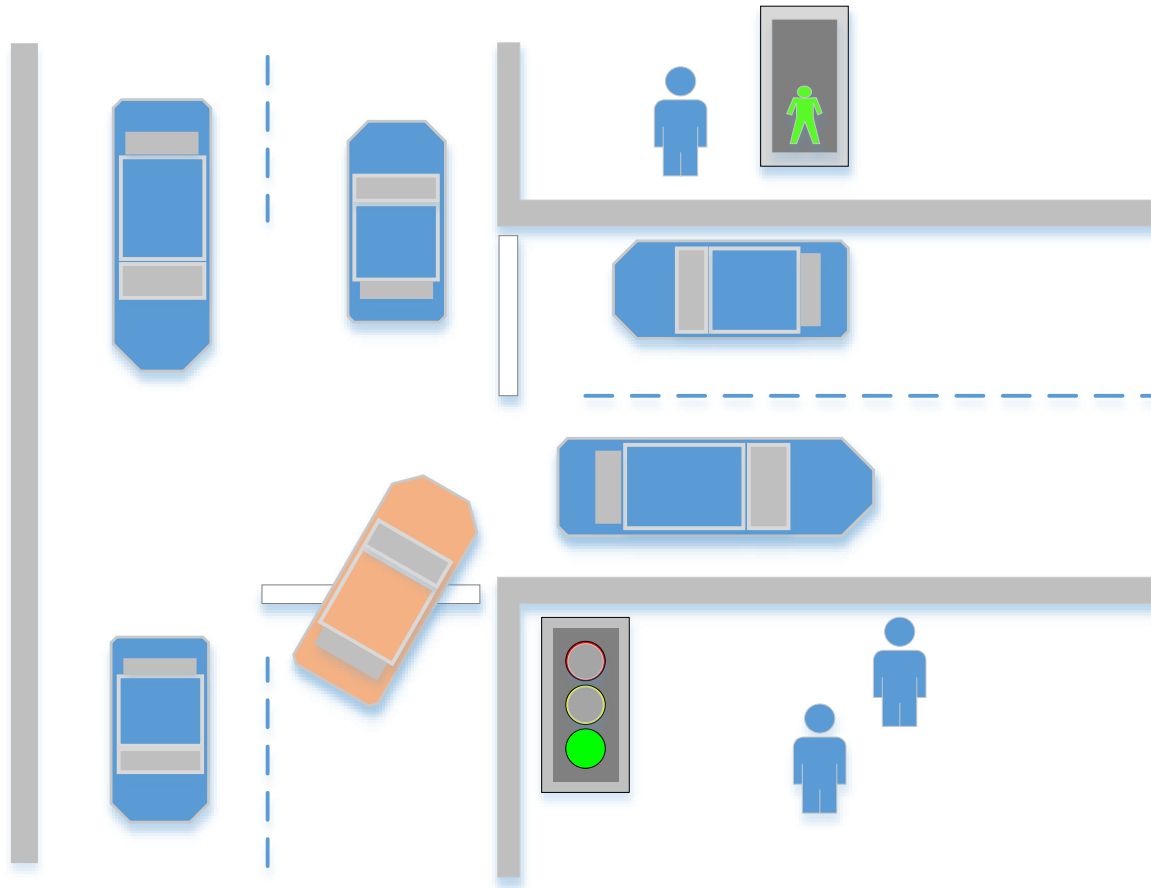
Contributions to the semantic analysis and formal representation of behavioral norms for automated driving

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Marcus Nolte¹, Jan Reich⁵, Torben Stolte¹, Markus Maurer¹

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What is an AV confronted with?



- societal aspects
- legal regulations



- traffic signs



- other traffic participants

How can we derive requirements in an open context that specify the desired vehicle behavior?

- ▶ designing an automated vehicle requires the elicitation and analysis of concerns about vehicle behavior

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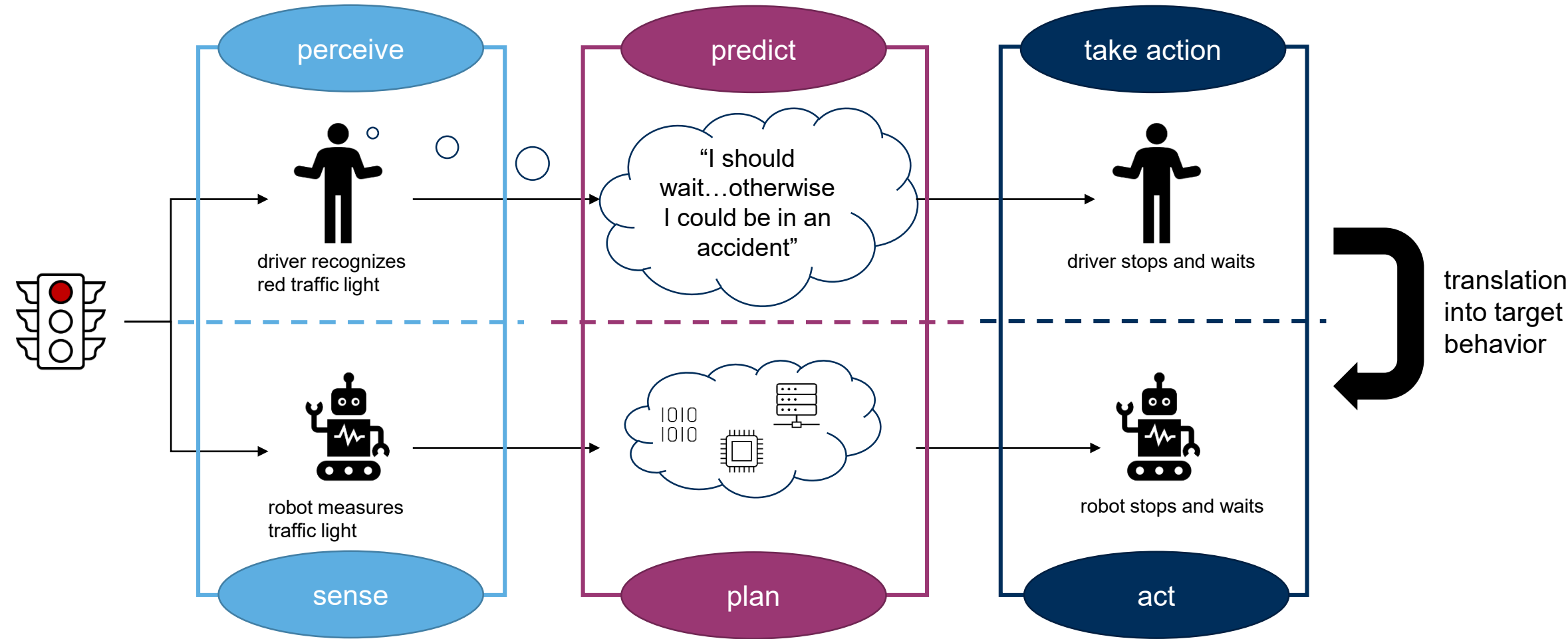
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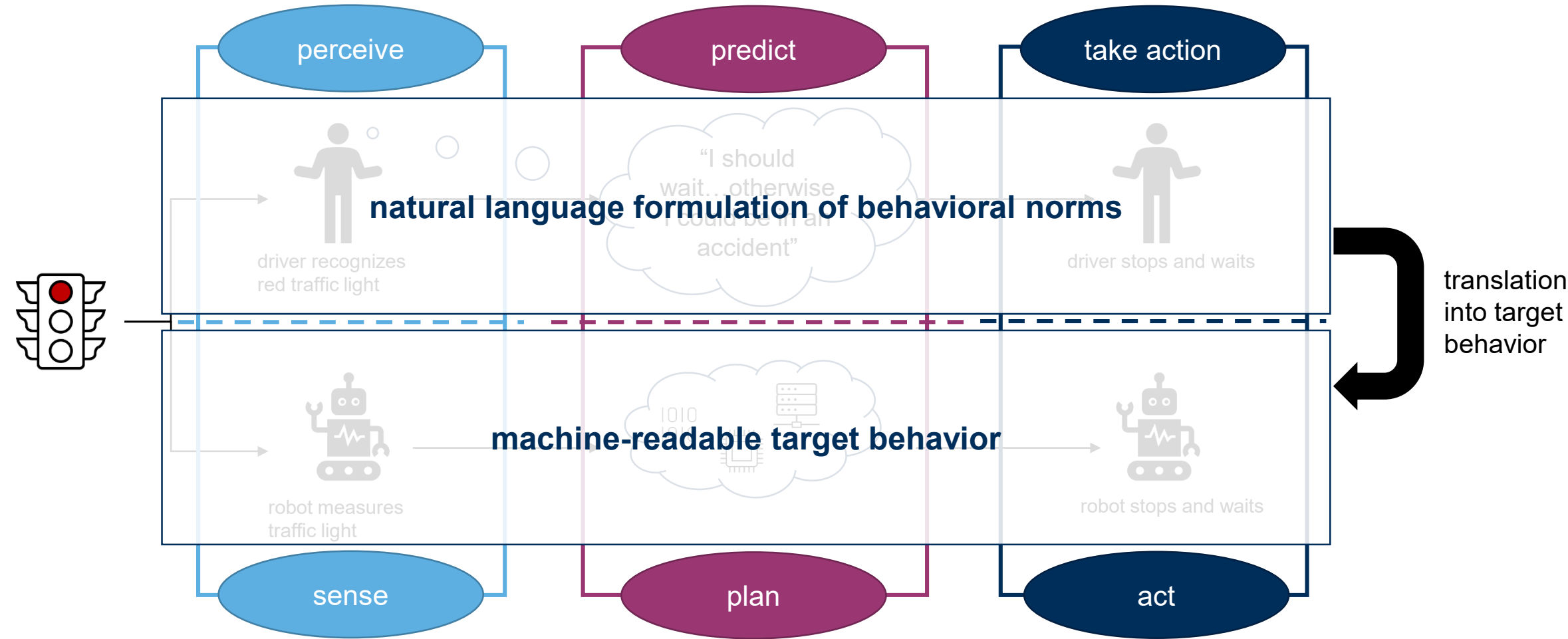


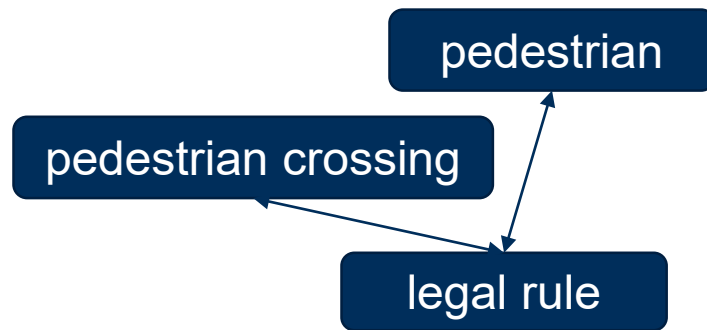
the semantic norm behavior analysis is designed to contribute to the documentation of these decisions

The foundation of target behavior

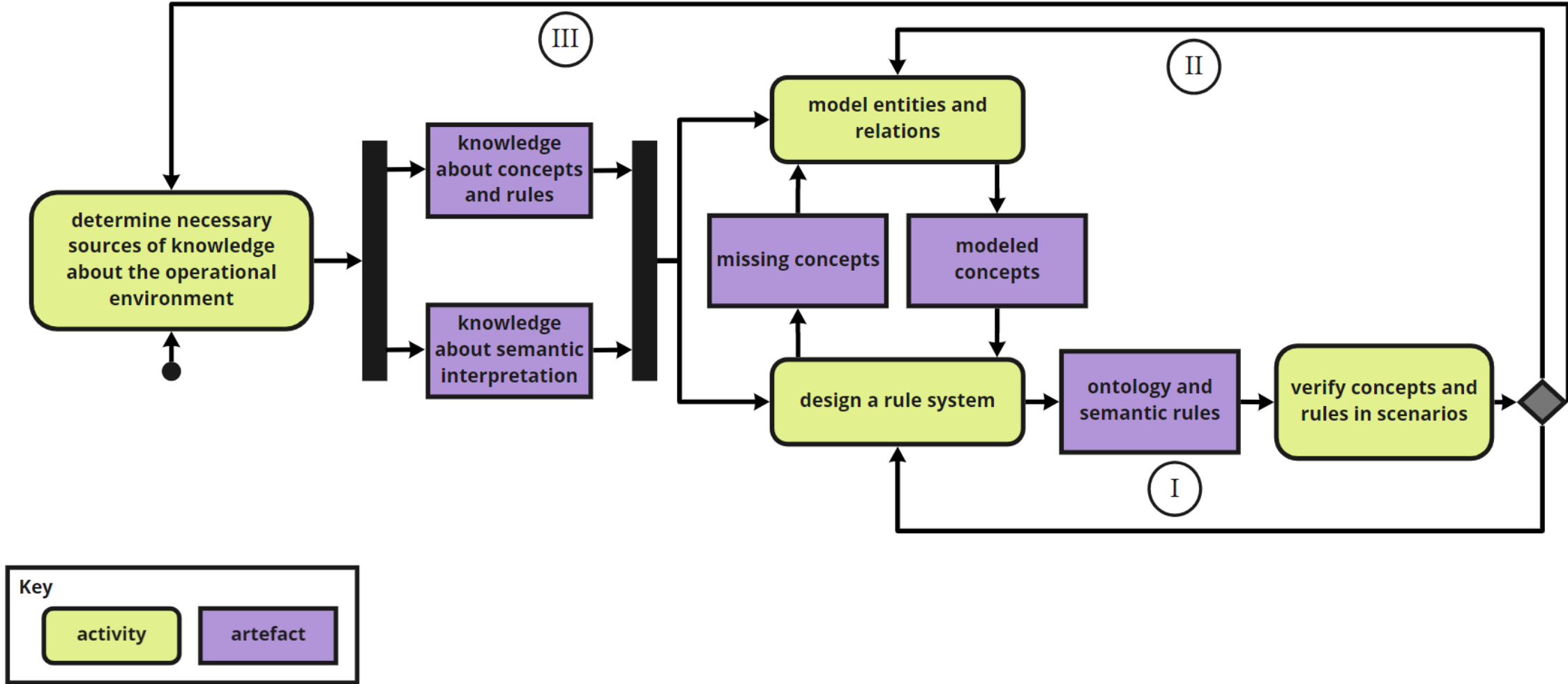


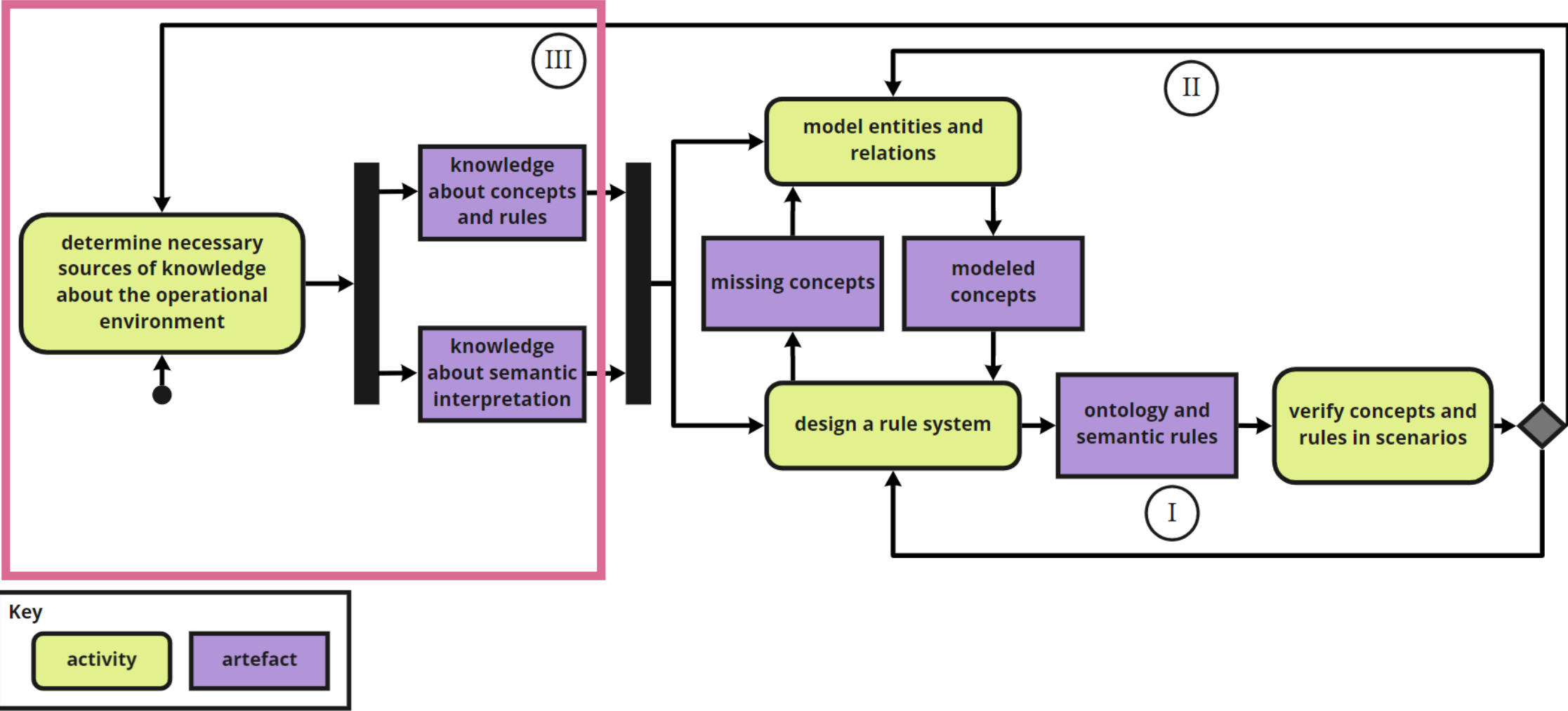
The foundation of target behavior



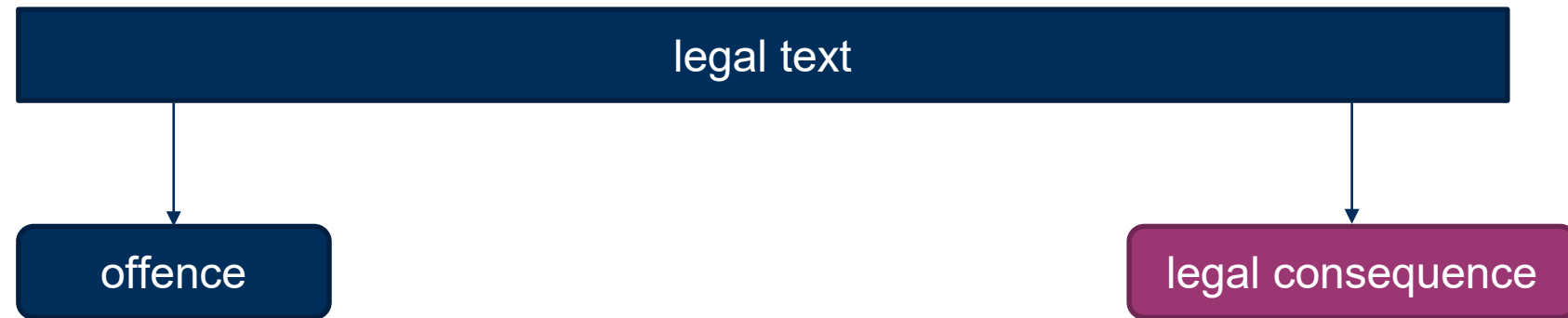


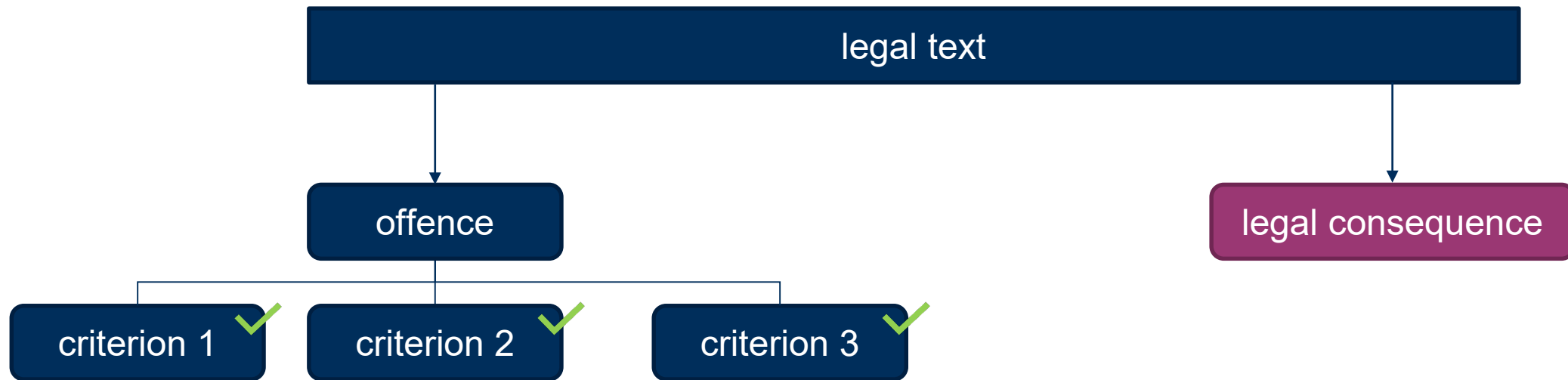
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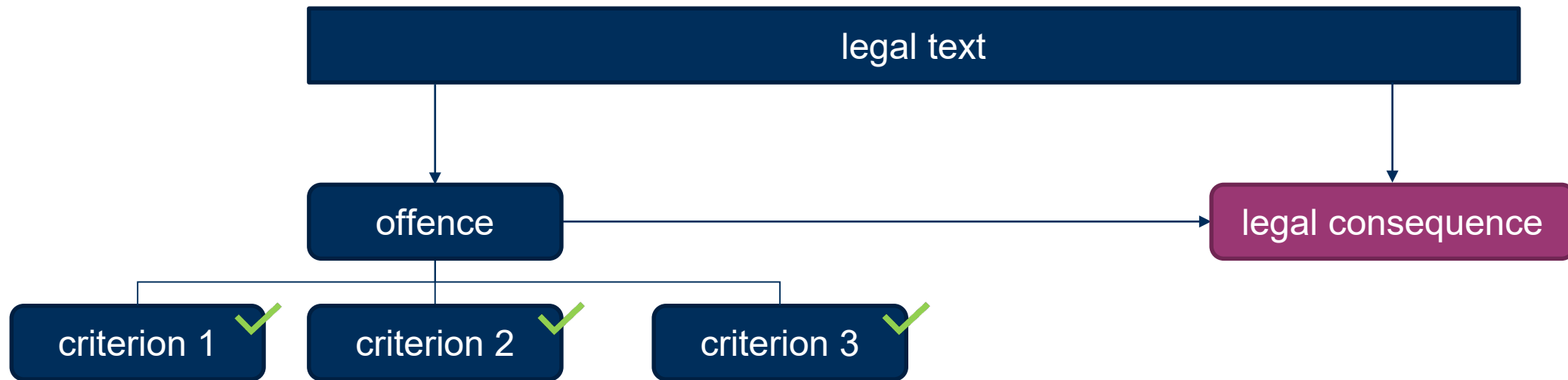




Semantic interpretation of legal texts (in Germany)









§ 26 German Traffic Code Pedestrian Crossings [translated by Salem]

- (1) At pedestrian crossings vehicles with the exception of rail vehicles **shall enable** crossing to pedestrians as well as wheelchair users, who want to noticeably use the pedestrian crossing.

offence

In that case vehicles may only drive with moderate speed. If necessary vehicles have to wait.

legal consequence



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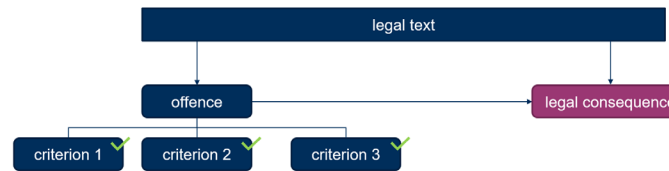
legal consequence

general driver interpretation (rule 0):

If
pedestrian crossing + noticeable
crossing intention of person



Then
drive slow or stop



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criterion 1

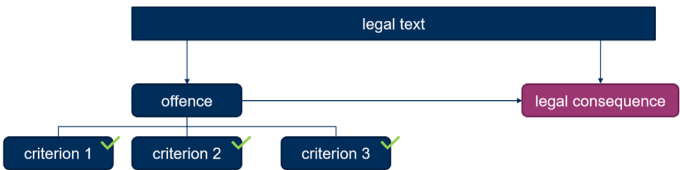
criterion 2

rule 0:

If pedestrian crossing + noticeable crossing intention of person then drive slow or stop

criterion 3

legal consequence



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criterion 1

How to recognize a pedestrian crossing?

criterion 2

What counts as “noticeable”?

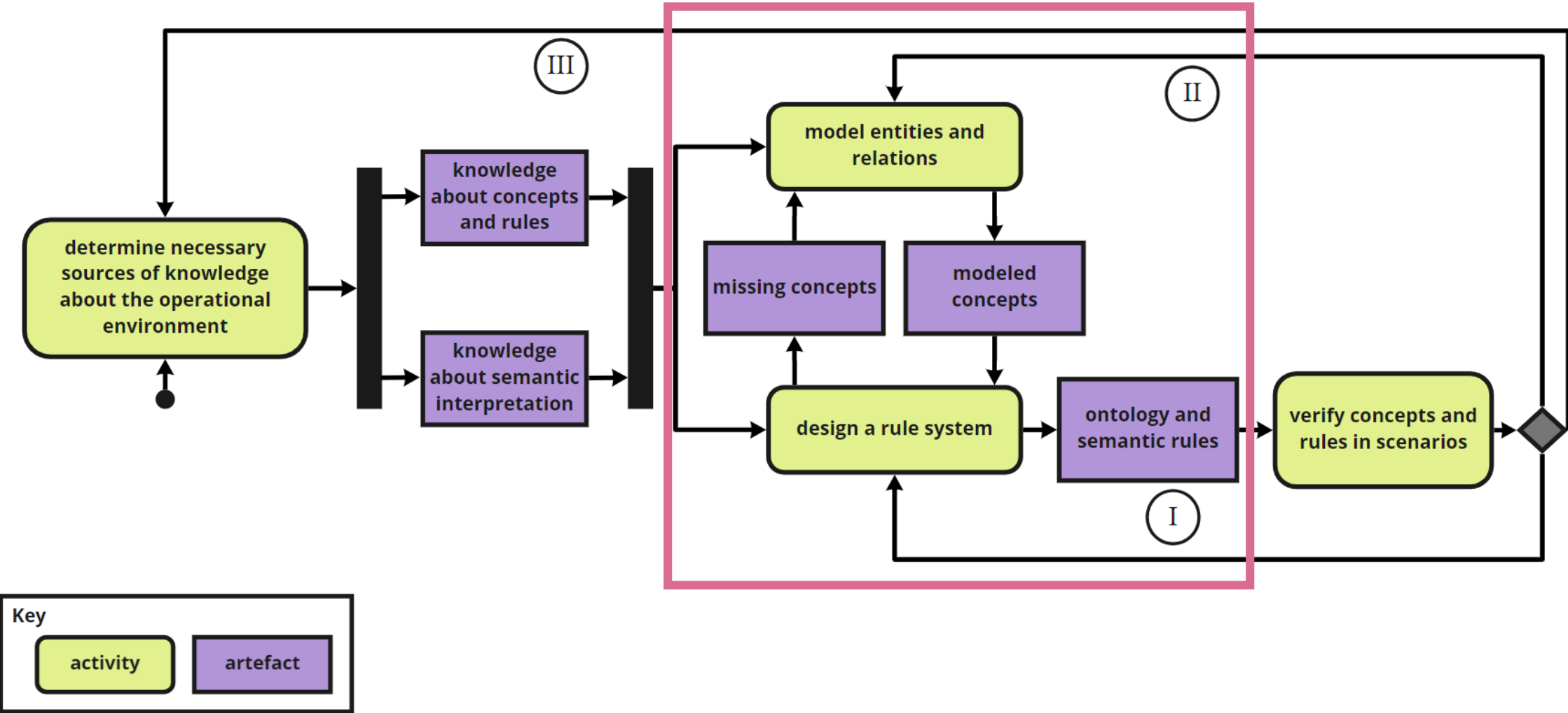
rule 0:

If pedestrian crossing + noticeable crossing intention of person then drive slow or stop

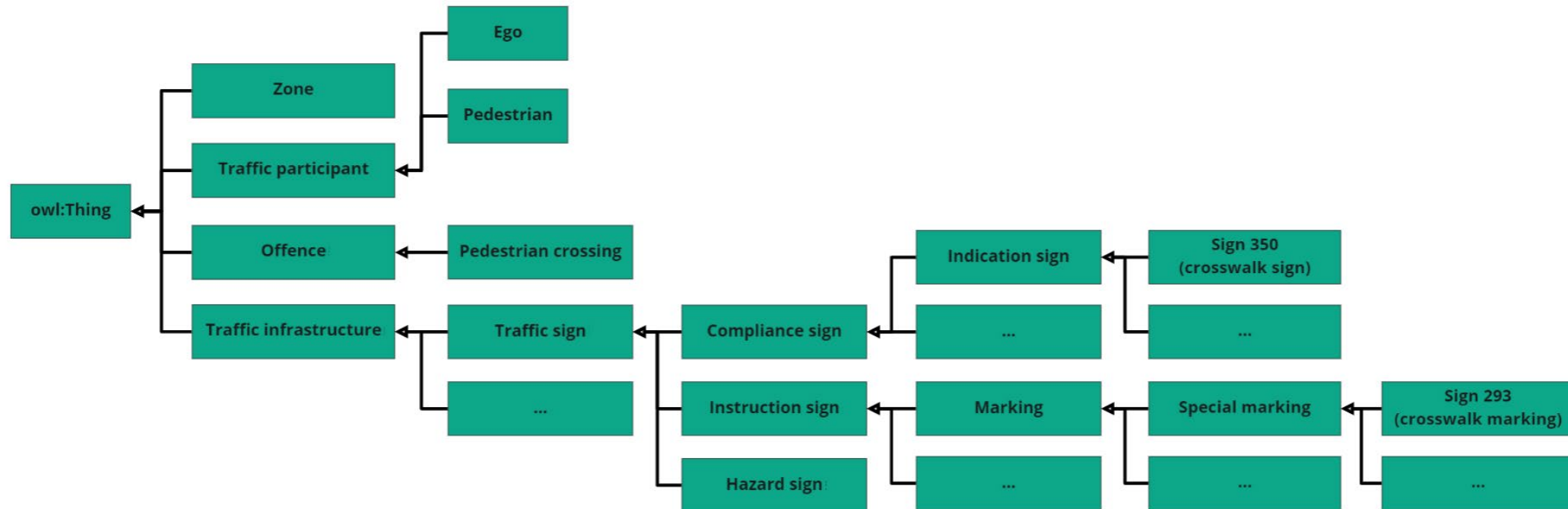
criterion 3

How to decide between slowing down and stopping?

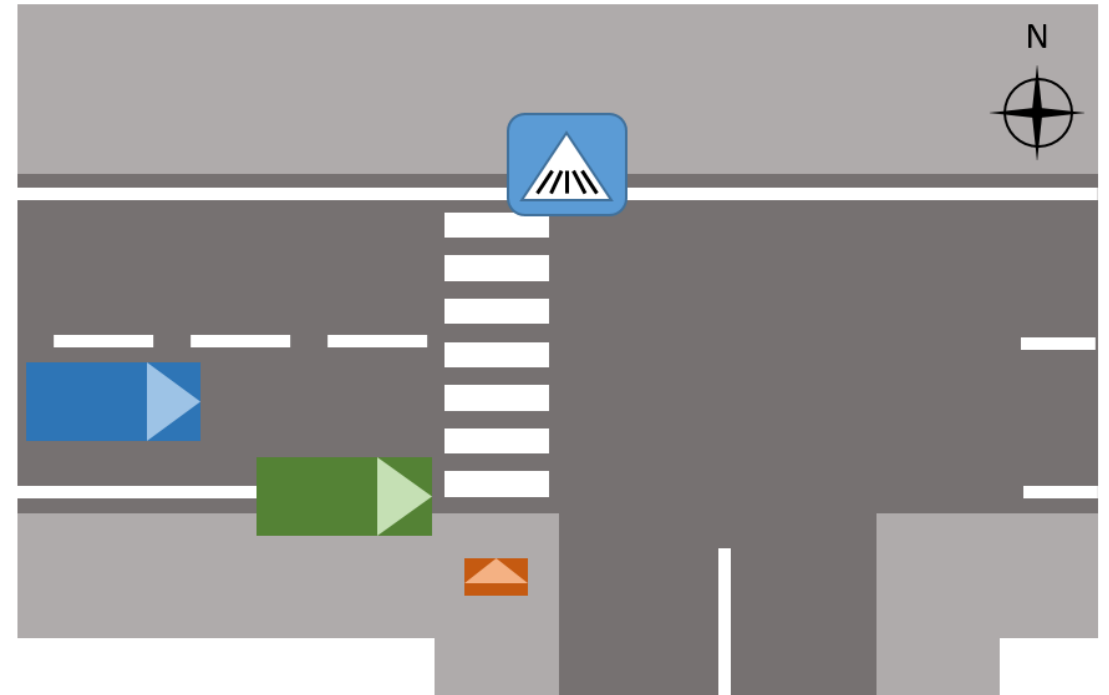
legal consequence



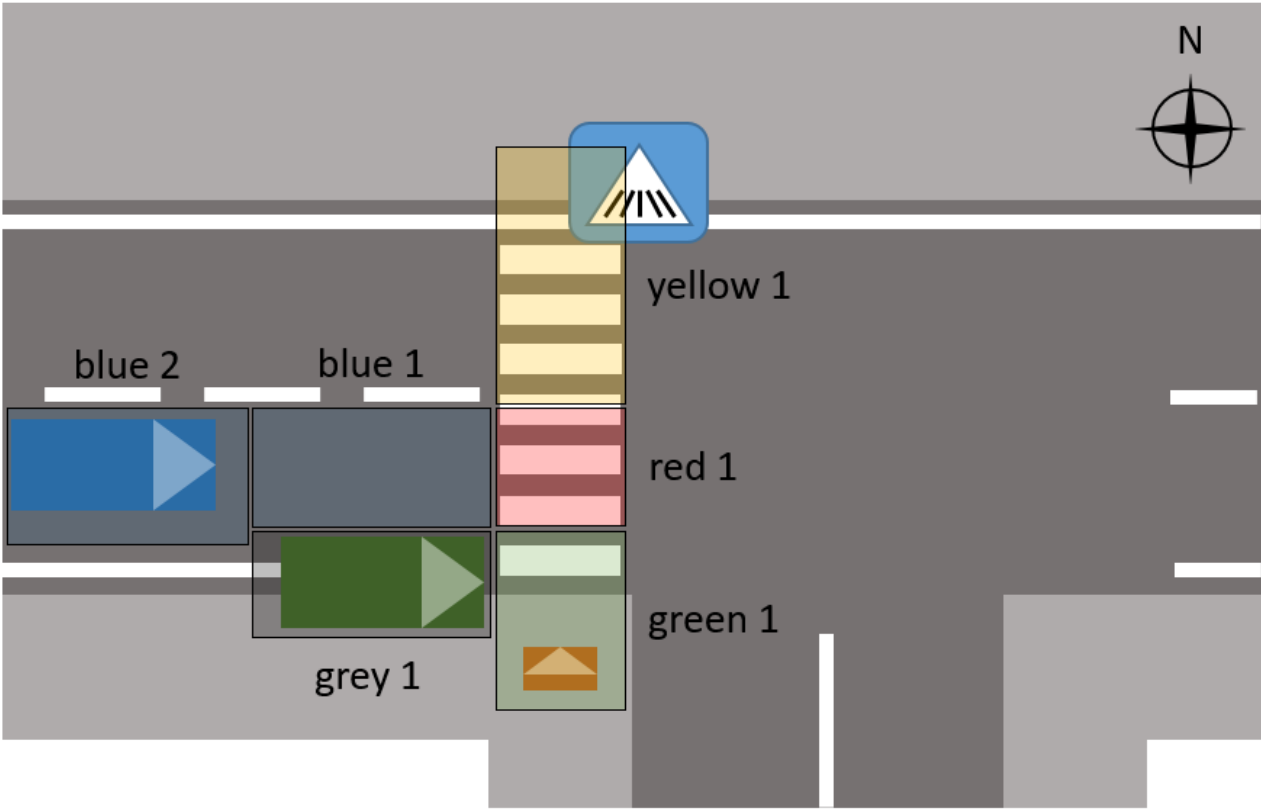
Top-down conceptualization



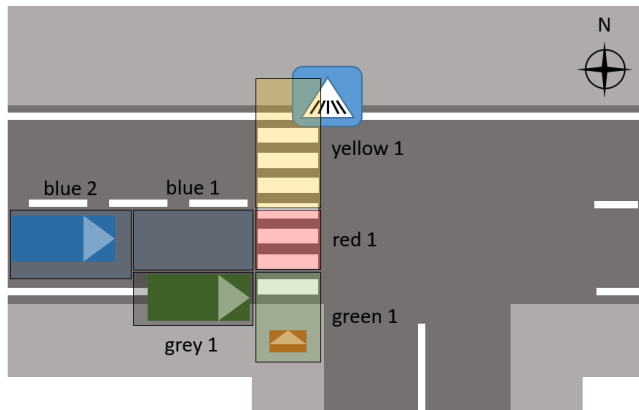
Exemplary scenarios



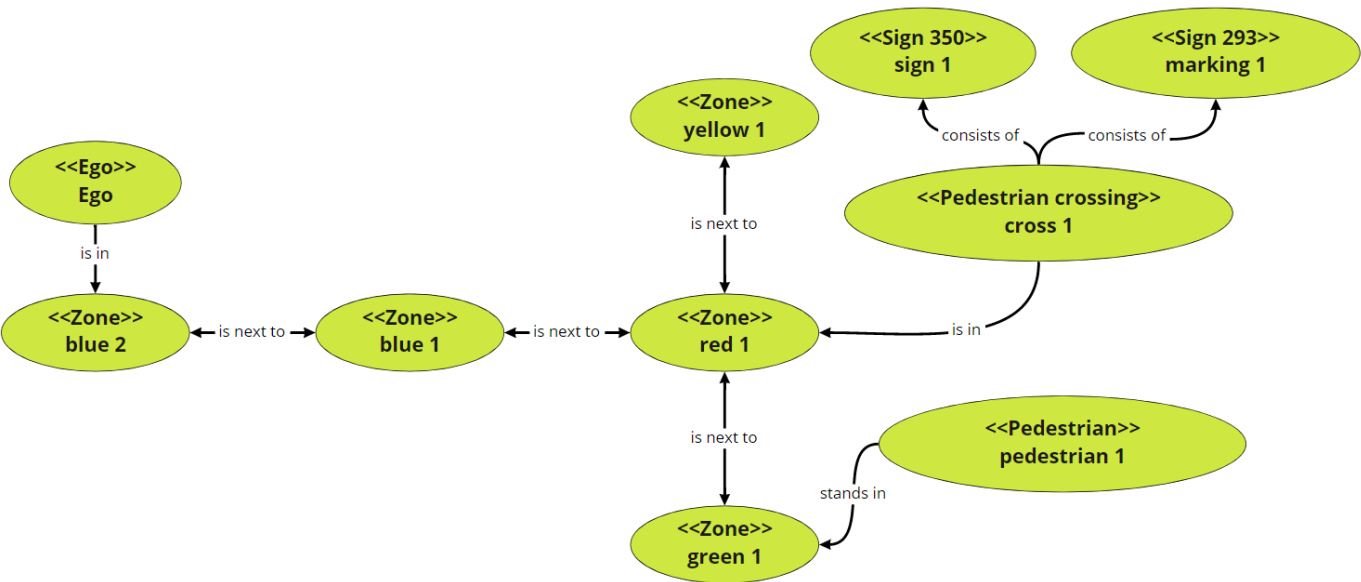
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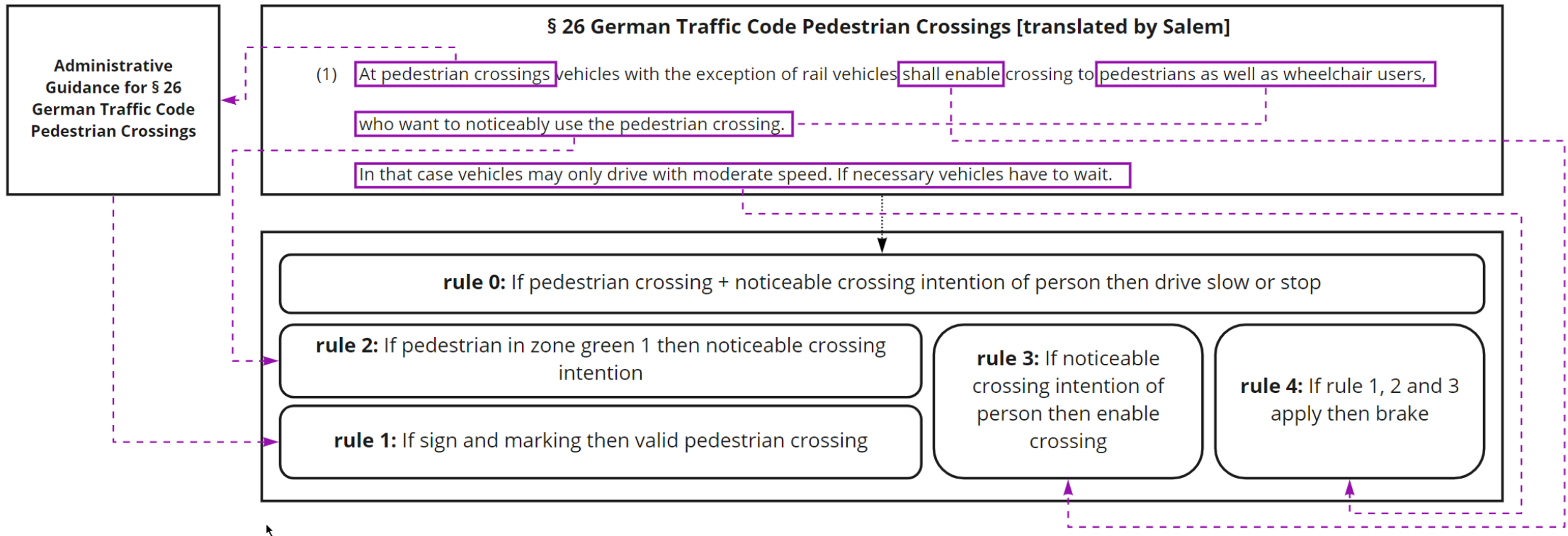


Scene

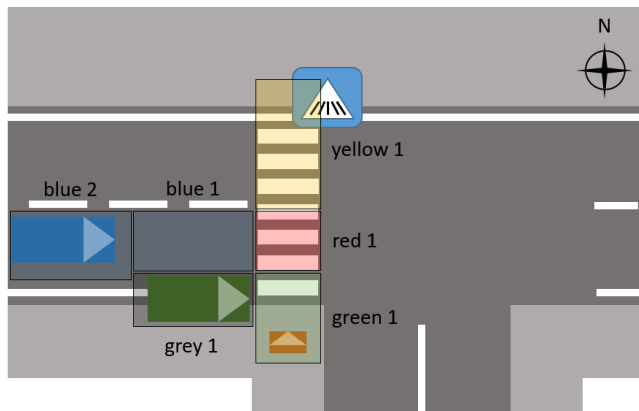


Ontology

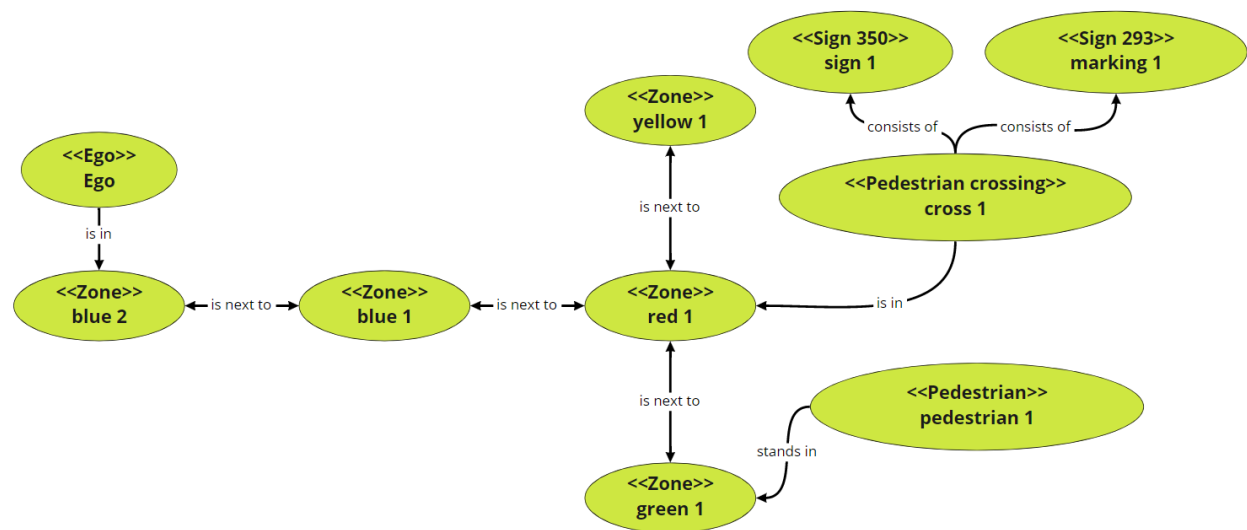




Scene

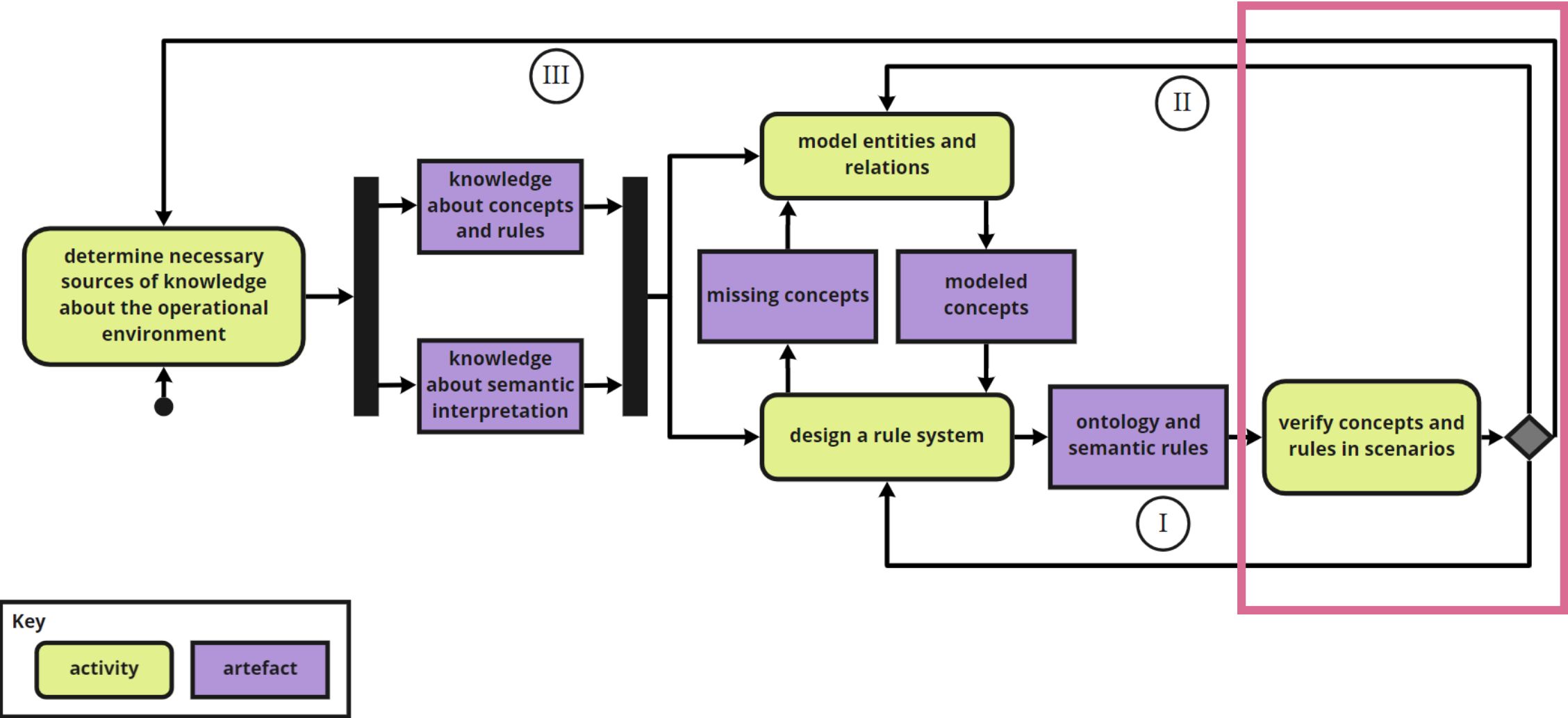


Ontology



Inference rule

Natural language rule	SWRL rule
If sign and marking then valid pedestrian crossing	<pre>Pedestrian_crossing(?cross) ^ sign_350(?sign) ^ sign_293(?marking) ^ is_fact(?sign, true) ^ is_fact(?marking, true) ^ consists_of(?cross, ?sign) ^ consists_of(?cross, ?marking) → is_fact(?cross, true)</pre>



Evaluating the target behavior rules

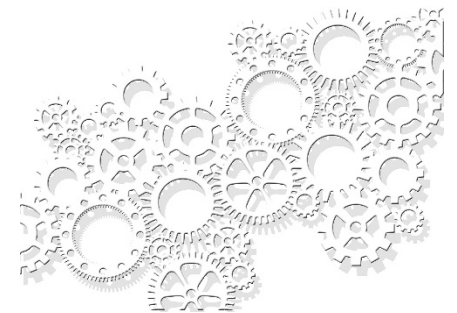


Evaluating the target behavior rules

- ▶ expert-based
 - ▶ analysis of a given scenario
 - ▶ comparison of the inferred target behavior with behavioral norms
- ▶ automated
 - ▶ logical consistency check of the formalized target behavior rules



[1]



[2]

[1] <https://pixabay.com/de/vectors/komische-charaktere-kritisches-denken-2026313/>

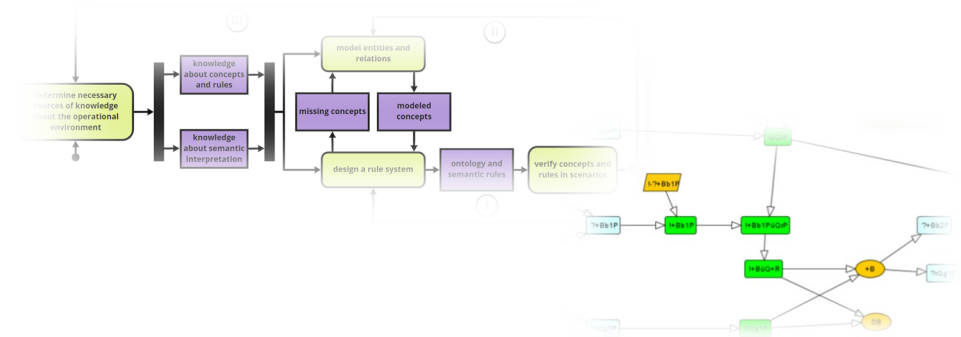
[2] <https://pixabay.com/de/illustrations/mechanik-zahnrad-zahn%c3%a4der-blau-551265/>

- ▶ paper contributions
 - ▶ argumentation of the semantic norm behavior analysis regarding the open traffic context
 - ▶ proposal of a first approach to systematically formulate target behavior
 - ▶ implementation of target behavior rules in a machine-readable format

► future work

- argumentation of the semantic norm behavior analysis regarding the open traffic context
- proposal of a first approach to systematically formulate target behavior
- implementation of target behavior rules in a machine-readable format

- resolve or moderate conflicting rules
- integration with the Phenomenon-Signal-Model
- synchronization with existing ontologies for scene representation



Thank you!

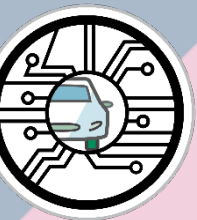
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