KI WISSEN
Automotive AI Powered by Knowledge

KI Wissen Final Event | 21-22 March 2024

Knowledge Formalization, Integration & Monitoring with Traffic Sequence Charts (TSCs)

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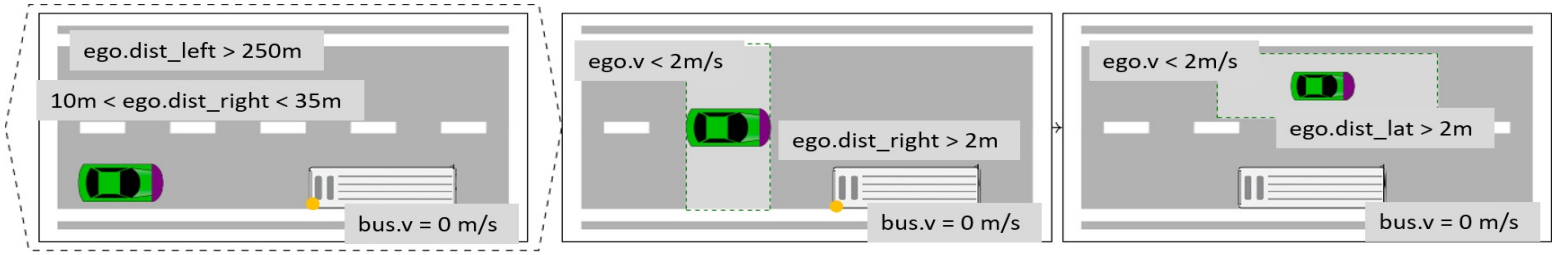
1

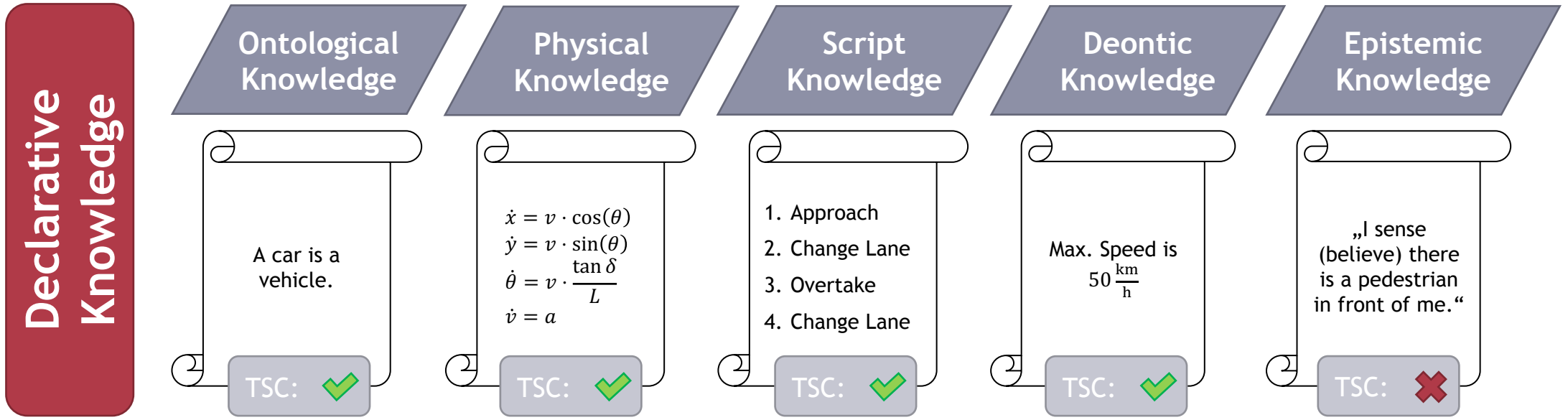
TP1 - Knowledge Integration

TP1 - Motivation

- Pass-by maneuver according to UC 2.9
  - Relevant Knowledge: Physical dynamics, distances, StVO rules
- Traffic Sequence Charts (TSCs) language
  - Visual yet formal language for scenario specification
- Merging different knowledge sources into a unified visual yet formal representation is beneficial
  - Intuitiveness
  - Understandability
- Research Questions
  - How to formalize such knowledge in TSCs?
  - How to integrate formalized knowledge into AI Training?



TP1 - TSC based Knowledge Classification and Formalization



- We categorized relevant multimodal knowledge describing *what* (Ontology) traffic objects *should* or *must* (Script, Deontic) do under *which* (Physics) dynamic capabilities.
- We investigated the capabilities of Traffic Sequence Charts (TSCs) to formalize such multimodal knowledge.

3.9
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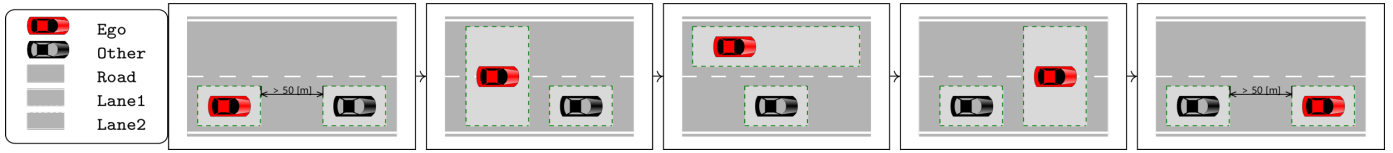
TP1 - Knowledge Application with Reinforcement Learning

- The declarative knowledge in TSCs describe *what* scenarios are to be realized.
- It is not clear on *how* to realize the scenarios
- Closing this gap with Reinforcement Learning
  - RL-Agent control vehicle through maneuvers satisfying the TSC
  - Invariant Based Reward function
- Active learning also considered in SotA-paper (AP1.1)

Declarative Knowledge



TSC 2RL

$$R = \begin{cases} 1 & \text{if } \varphi_E, \\ 0.75 & \text{if } \varphi_D \wedge \neg\varphi_E, \\ 0.5 & \text{if } \varphi_C \wedge \neg\varphi_D \wedge \neg\varphi_E, \\ 0.25 & \text{if } \varphi_B \wedge \neg\varphi_C \wedge \neg\varphi_D \wedge \neg\varphi_E, \\ 0 & \text{if } \varphi_A \wedge \neg\varphi_B \wedge \neg\varphi_C \wedge \neg\varphi_D \wedge \neg\varphi_E, \\ -1 & \text{otherwise.} \end{cases}$$

Declarative Knowledge

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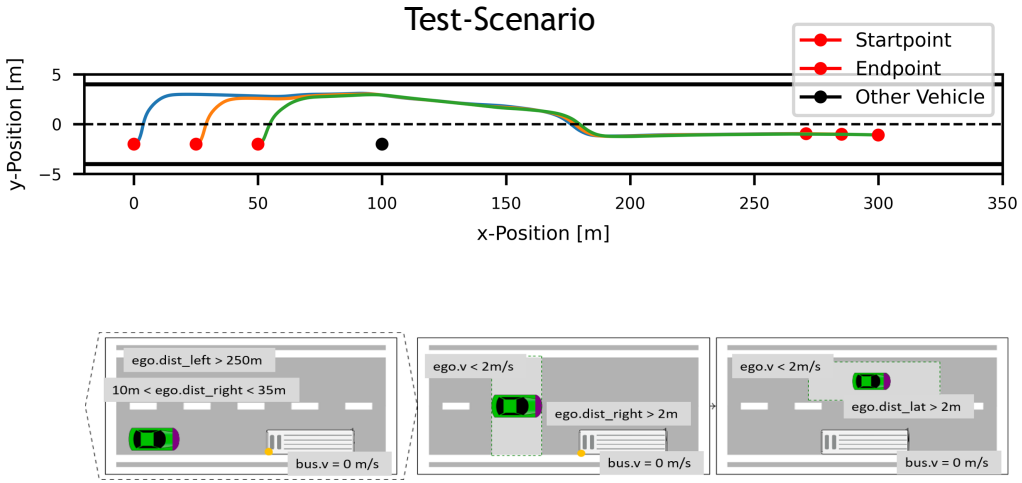
2

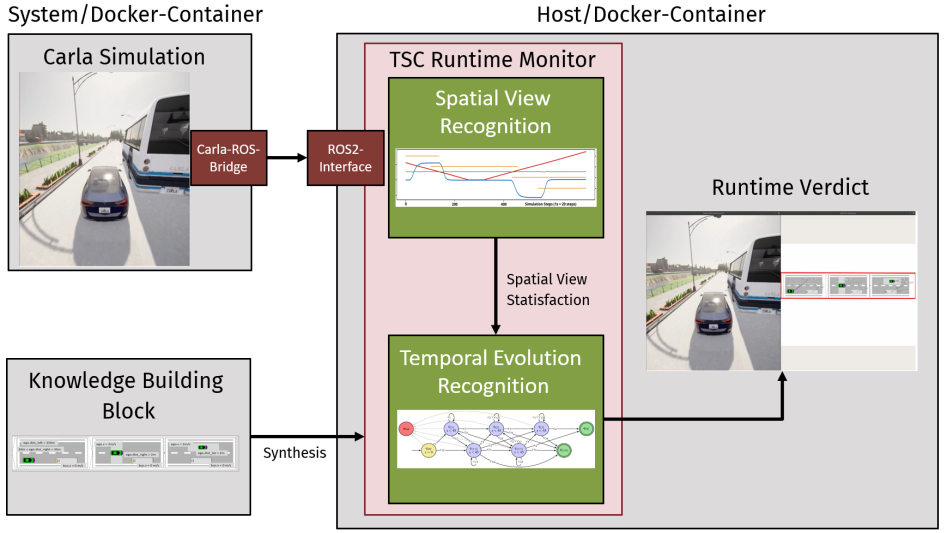
TP3 - Knowledge Conformity

TP3 - Runtime Monitoring - Motivation

- TSCs can be used to formalize multimodal knowledge
- TSC-based knowledge specification can be considered in Reinforcement Learning (RL)
- Knowledge conformance of RL agent is not guaranteed
  - ➡ Runtime Monitoring for TSC-based knowledge specifications



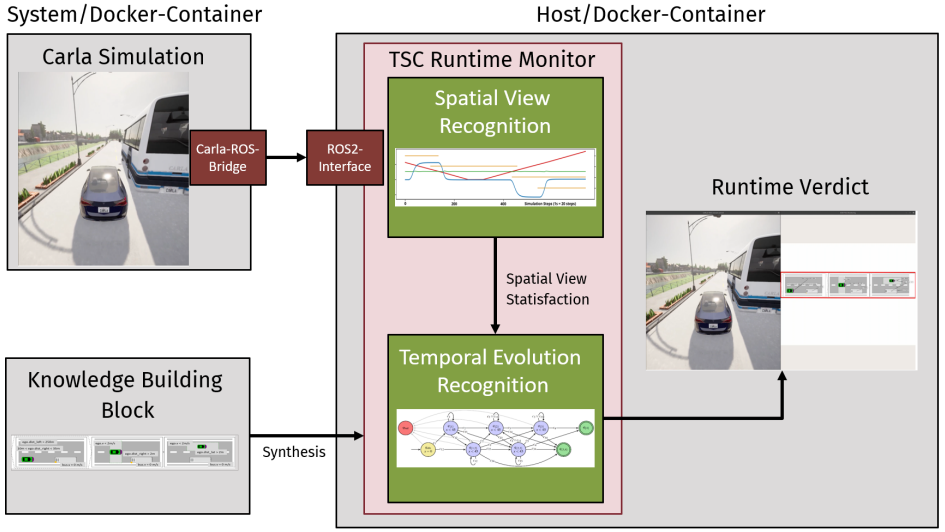
Multi-Stakeholder Knowledge Specification



Runtime Monitoring for Knowledge Conformity

TP3 - Runtime Monitoring - Concept

- Continuous verdicts about Traffic Sequence Charts (TSCs) compliance during runtime
- Exploiting the structure of TSC formalism
- Separation of concerns w.r.t
  - Spatial properties: Spatial View Recognition (SVR)
  - Temporal properties: Temporal Evolution Recognition (TER)
  - Monitor provides verdict: satisfied, violated or inconclusive



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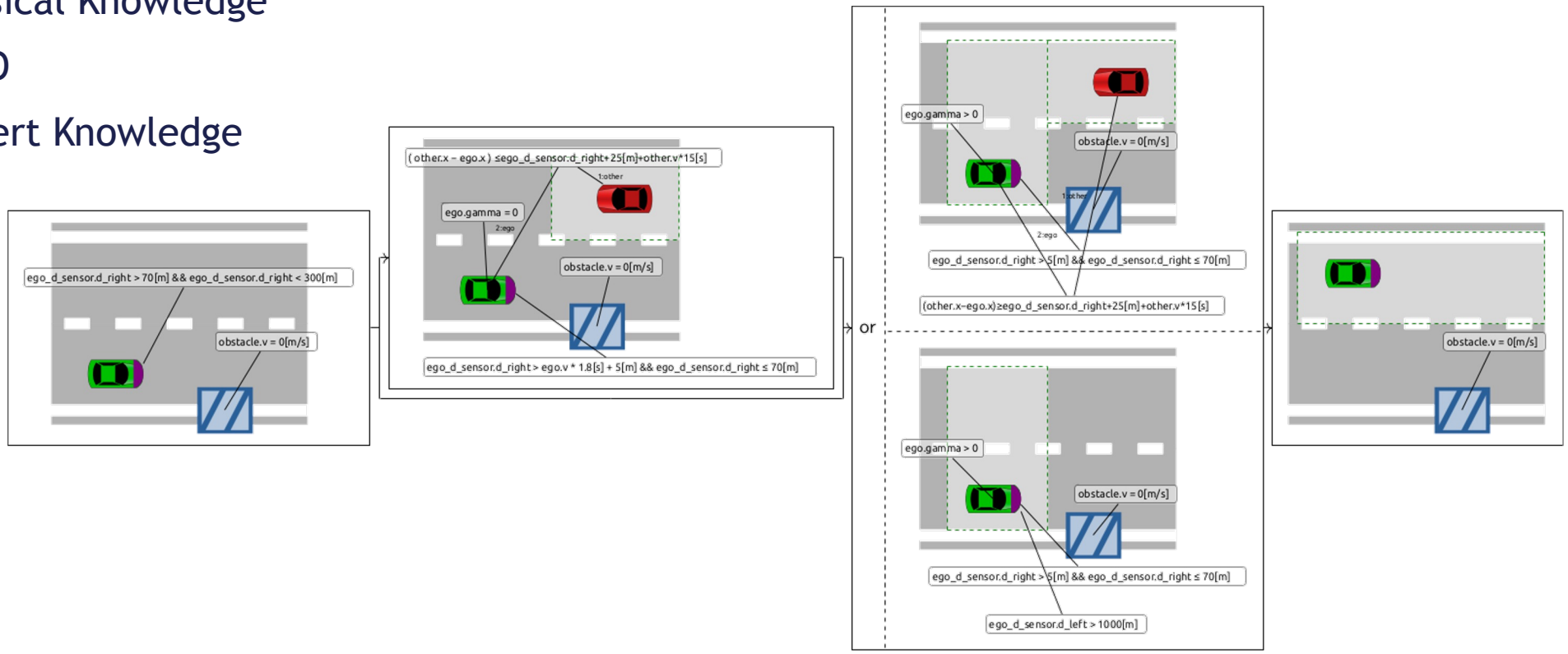
TP3 - Runtime Monitoring - Example (1)

"We want to monitor, if the decision to start passing-by the obstacle is correct."

- Physical Knowledge
- StVO
- Expert Knowledge



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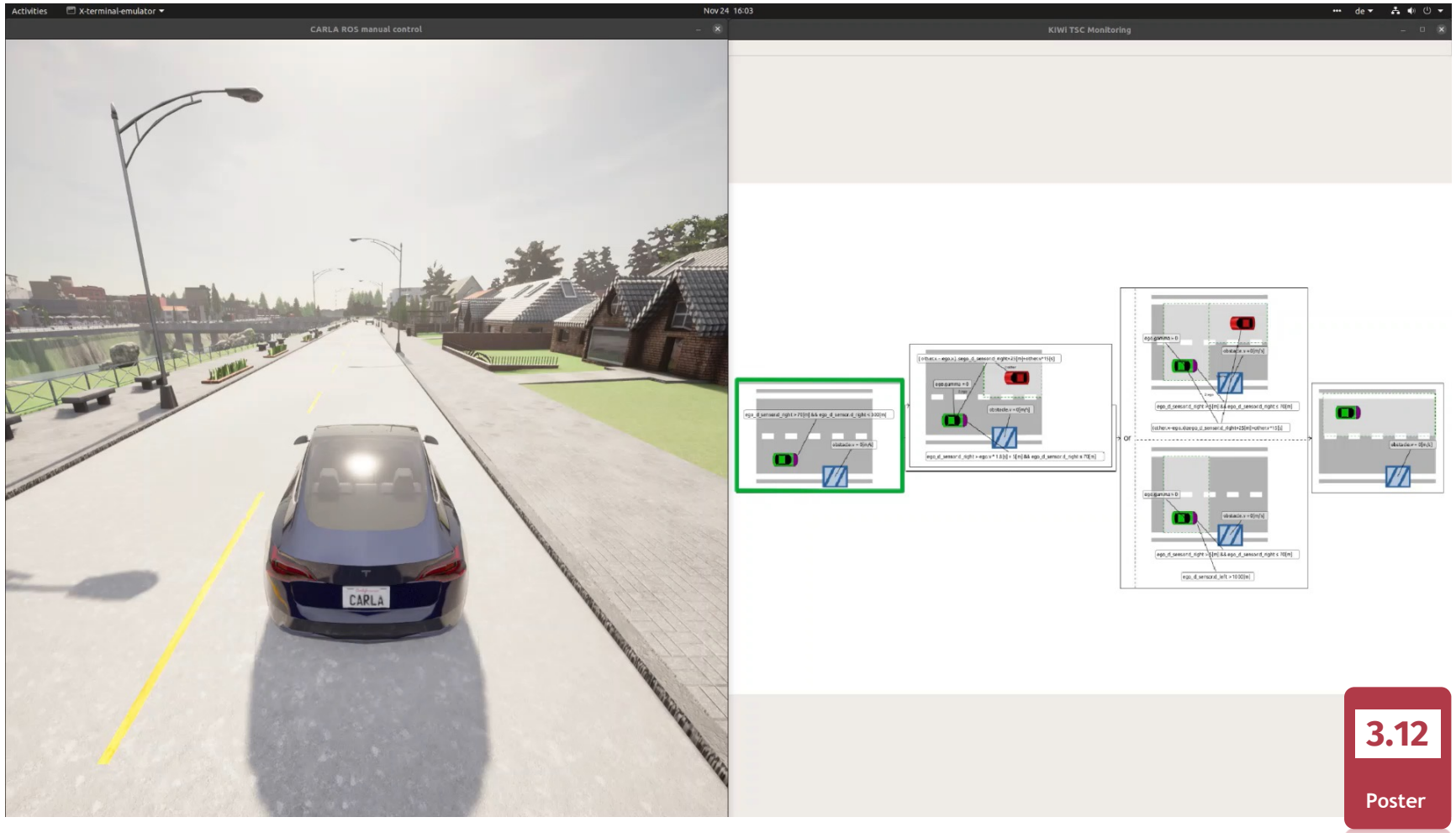
TP3 - Runtime Monitoring - Example (2)

- TSC Runtime Monitoring integrated into CARLA Simulation via ROS interface
- System-Under-Test behaviour ***satisfies*** specified knowledge



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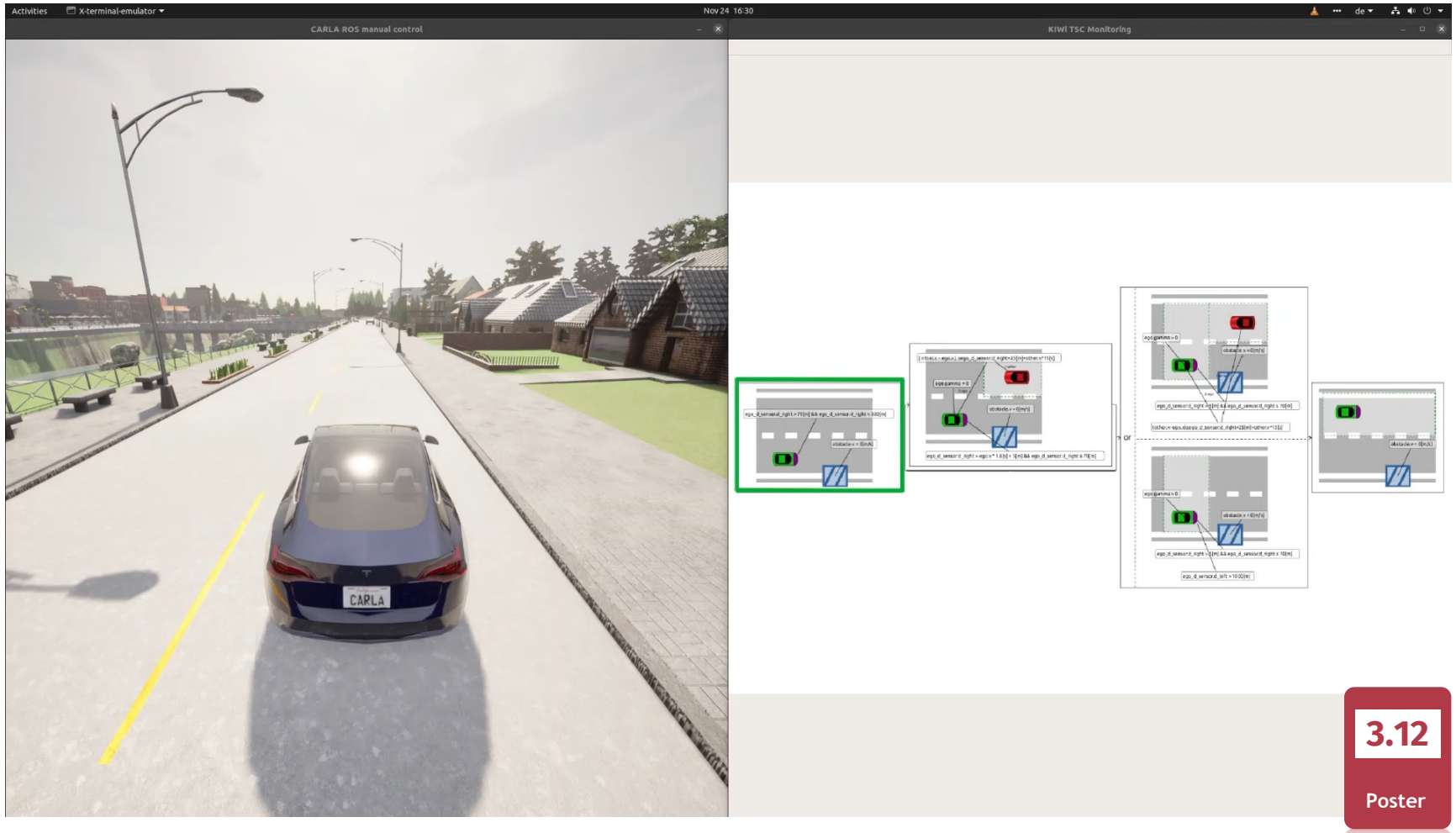
TP3 - Runtime Monitoring - Example (3)

- TSC Runtime Monitoring integrated into CARLA Simulation via ROS interface
- System-Under-Test behaviour ***violates*** specified knowledge
- No sufficient distance to oncoming traffic



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Monitoring of TSC-based Knowledge Specification

- Overall system monitoring (AI-module incl. shielding and safety mechanisms), planned usage:
  - Early detection of wrong system behavior
  - Quick insights on interferences and cause-effect relations
  - Supports efficient verification
  - Efficient trigger for safety mechanisms

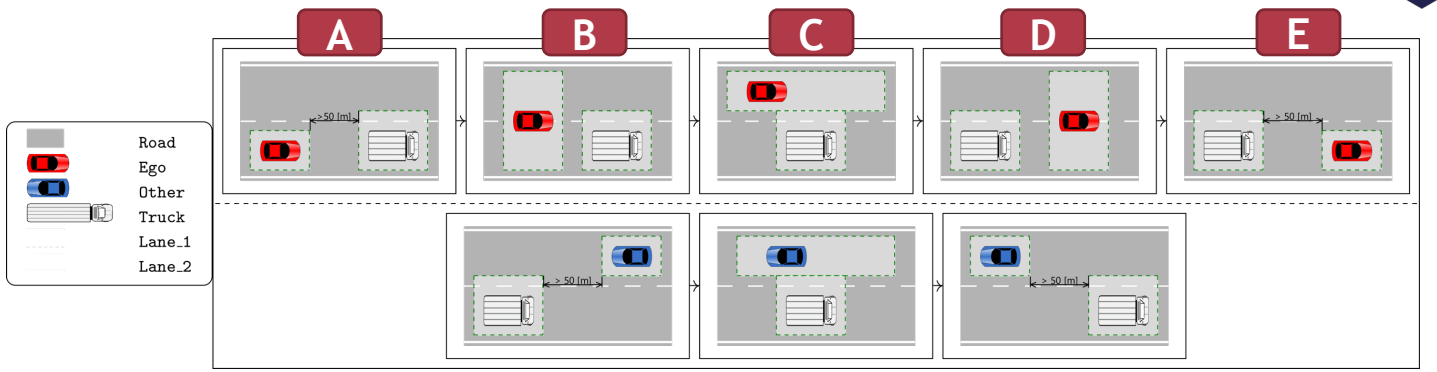
- Foundation for variety of future applications
  - Plausibilization of Generative AI – Monitoring, excluding shielding and safety mechanisms
  - ODD Monitoring – Detection of ODD violations or novelty detection
  - Explainability – Monitoring of system and environment to explain future behavior

3

TP4 - Enabler, Integration & Demonstration

TP4 - TSC-Based Generation of Concrete Scenarios

- Another approach to realize TSC scenarios is to transfer TSCs in satisfiability problem [1]
- Each SMT solution is a concrete scenario
- Solving the SMT formula multiple times resulting in various scenarios
- Simulation of Scenarios in poster session



Satisfiability Problem (SMT)

SMT Solving & Variation

- Solver seed variation
- Recursive blocking according to all_smt algorithm from z3-solver [2]
  - Along Random Terms
  - Along Invariants A, B, C, D, E

Scenarios

3.17
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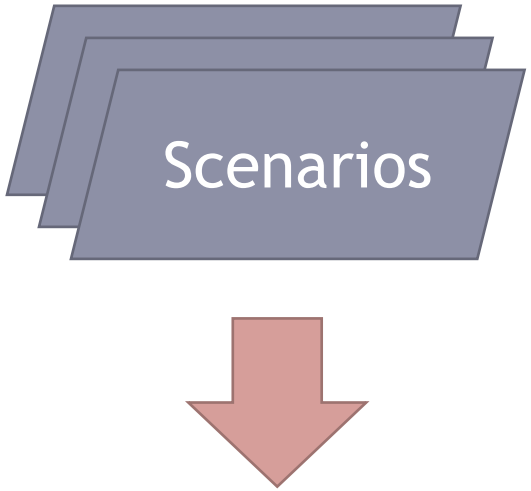
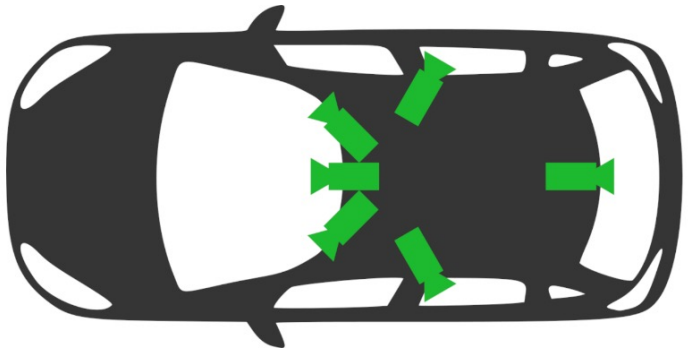
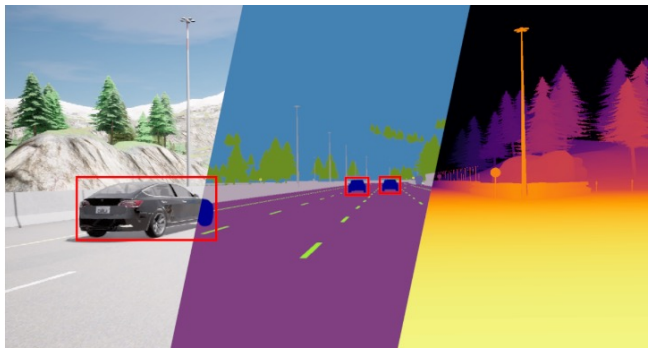
[1] Becker et al. (2022) Simulation of Abstract Scenarios: Towards Automated Tooling in Criticality Analysis. In: Autonomes Fahren. Ein Treiber zukünftiger Mobilität Zenodo. Pages 42-51. doi: 10.5281/zenodo.5907154.

TP4 - TSC-Based Generation of Concrete Scenarios

- **Synthetic Data Generation**
  - Generation of 300 scenarios with recursive blocking method
  - Simulation with CARLA and using sensor setup to record data
  - 300 GB Dataset from 6 vehicle-mounted and 2 off-side cameras incl.
    - Semantic & instance segmentation
    - 2D & 3D bounding boxes
    - Depth maps & vehicles trajectories







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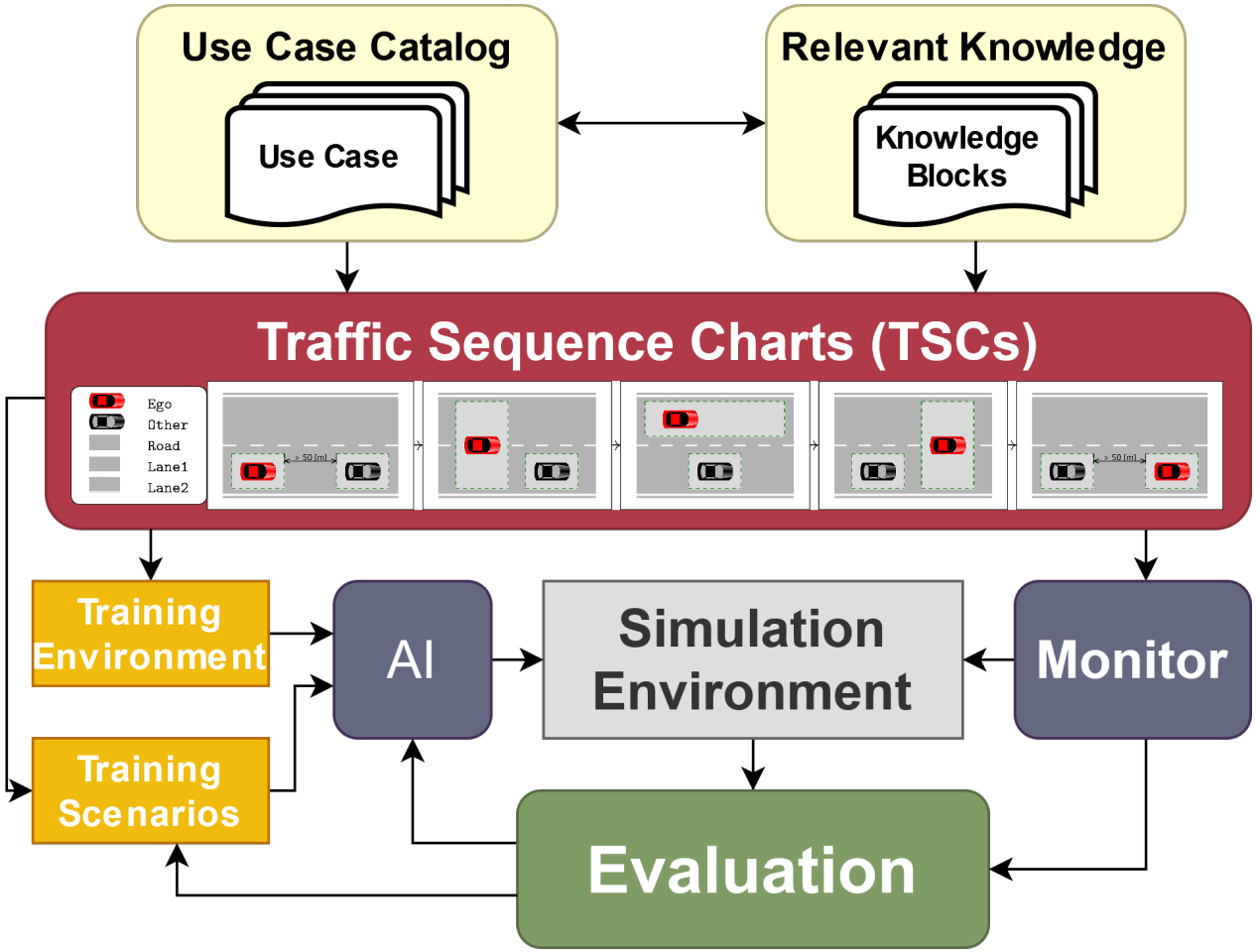
Summary

- **TP1 – Knowledge Integration**
  - Formalize multimodal knowledge with TSCs (11 Knowledge Building Blocks)
  - Integrate Knowledge via RL
- **TP3 – Knowledge Conformity**
  - Runtime Monitoring for TSCs
  - Knowledge compliance in Carla
- **TP4 – Enabler, Integration & Demonstration**
  - Variation of scenarios based on SMT solving methods
  - Generating 300 GB synthetic data



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