KI WISSEN

Automotive AI Powered by Knowledge

KI Wissen Final Event | 21-22 March 2024

Enabling, Integration & Demonstration

Federica Paolicelli | AVL

Enabling, Integration & Demonstration

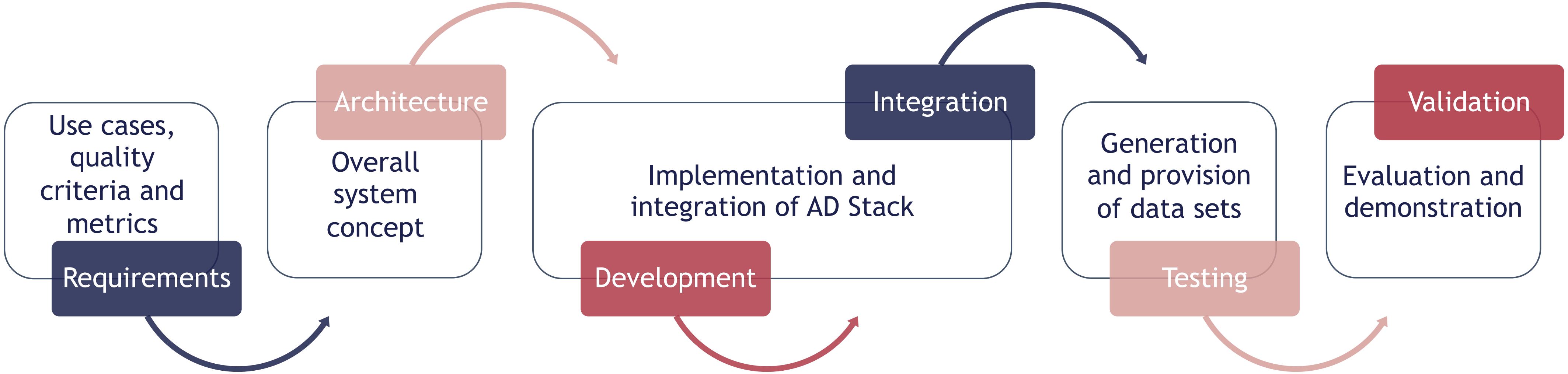
TP4 did not aim to integrate any specific knowledge into AI-based methods. Instead, it served as support to the other TPs.

TP4 provided a simulation environment and an overall system architecture in which the AI-based components could be integrated.

A shared demonstrator was set up to validate the new components not only individually, but also in the context of the overall system.

Organization & Objectives

The sub-project followed a software development process-like structure:



Requirements
Use cases, quality criteria and metrics

Architecture
Overall system concept

Development

Integration
Implementation and integration of AD Stack

Testing
Generation and provision of data sets

Validation
Evaluation and demonstration

Goals & Challenges

- Create a catalogue of use case scenarios
- Define evaluation metrics
- Setup a shared demonstrator
- Enhance the AD-Stack
- Integrate new AI modules into the demonstrator
- Create simulation scenarios
- Generate synthetic driving data
- Provide real-world driving data

- Ensuring that the implementation details of the core modules, the information flow in the overall system, and the processing of sensor data can be separated from the implementation of new AI functions.
- Providing maximum flexibility in the design of new AI modules.
- Designing the development process so that the integration does not take place all at once at a late stage of the project but is an integral part of the incremental development process.

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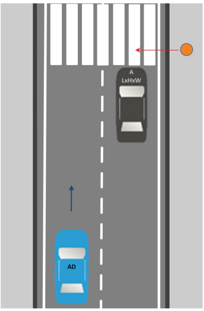
» Use Cases, Quality Criteria & Metrics

Use Case Scenario Catalog

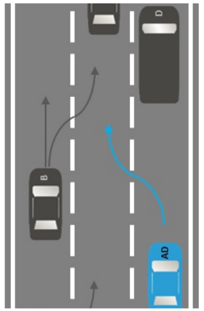
KI Wissen planned to apply the developed AI modules to three automotive Use Cases (UC):



UC1: Pedestrian Detection under Occlusion

- Improve the ability to perceive and track pedestrians who are partially or completely obstructed from view.

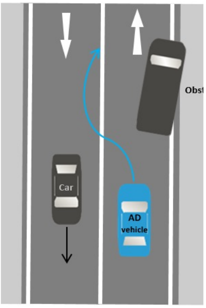
- Mathematical and Physical Knowledge



UC2: Complex Lane Change

- Improve the long-term prediction of the traffic scene to gain a better understanding of the overall situation.

- World Knowledge



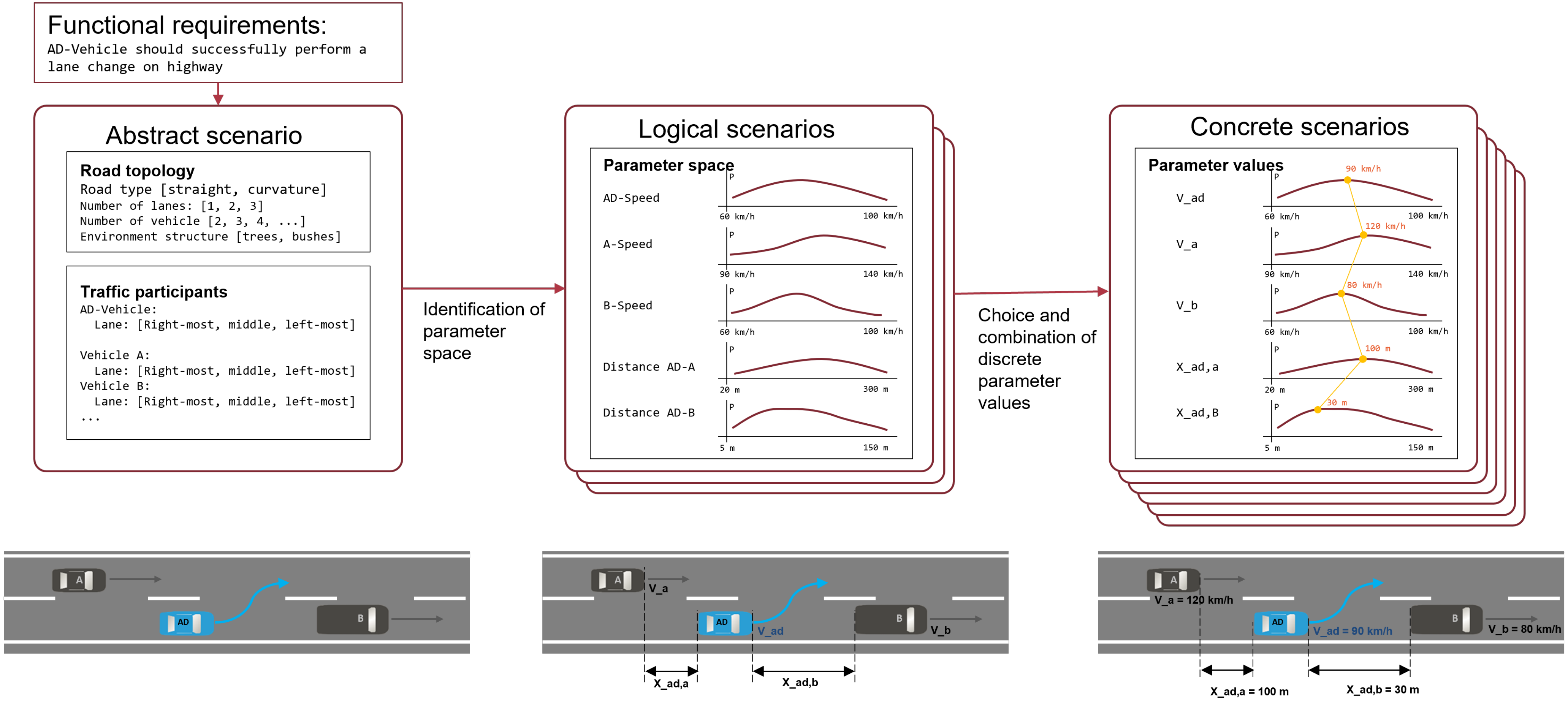
UC3: Controlled Rule Exception

- Improve understanding of traffic situations with conflicting rules and goals and enhance driving behavior.

- Normative Knowledge, Knowledge Extraction

Deriving the Test Scenarios

PEGASUS Method



Functional requirements:
`AD-Vehicle should successfully perform a lane change on highway`

Abstract scenario

Road topology
```
Road type [straight, curvature]
Number of lanes: [1, 2, 3]
Number of vehicle [2, 3, 4, ...]
Environment structure [trees, bushes]
```

Traffic participants
```
AD-Vehicle:
  Lane: [Right-most, middle, left-most]

Vehicle A:
  Lane: [Right-most, middle, left-most]
Vehicle B:
  Lane: [Right-most, middle, left-most]
...
```

Identification of parameter space

Logical scenarios

Parameter space

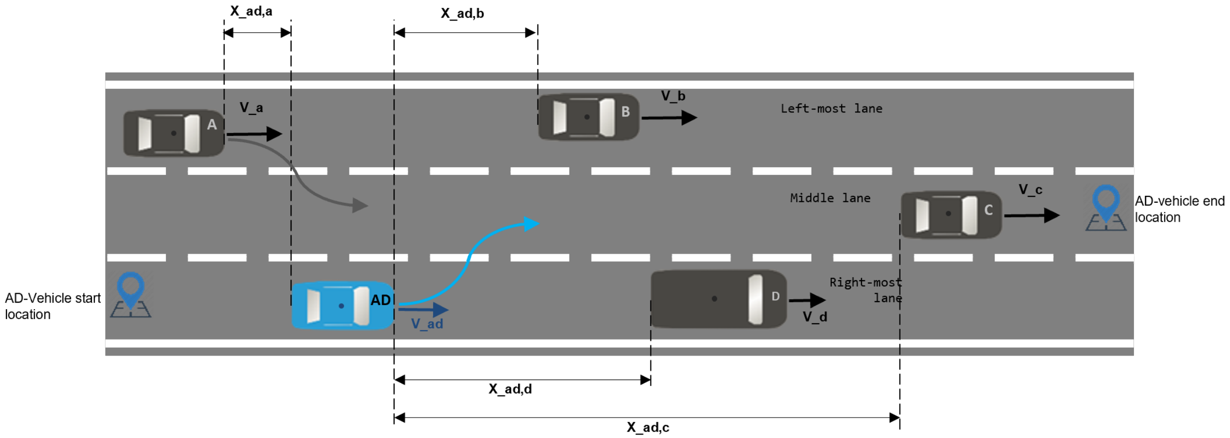
Choice and combination of discrete parameter values

Concrete scenarios

Parameter values

Example of Concrete Scenarios

UC2.4



	AD-Vehicle	Vehicle A			Vehicle B			Vehicle C			Vehicle D		
Test ID	V_ad [km/h]	V_a [km/h]	X_ad,a [m]	Change lane?	V_b [km/h]	X_ad,b [m]	Change lane?	V_c [km/h]	X_ad,a [m]	Change lane?	V_d [km/h]	X_ad,d [m]	Change lane?
UC2.4_AS01 01	90	120	50	yes	120	50	no	n/a	n/a	n/a	80	100	no
UC2.4_AS01 02	90	120	50	yes	120	50	yes	n/a	n/a	n/a	80	100	no
UC2.4_AS01 03	90	120	50	yes	120	50	yes	110	150	no	80	100	no
UC2.4_AS01 04	100	120	50	yes	120	50	no	n/a	n/a	n/a	80	100	no
UC2.4_AS01 05	100	120	50	yes	120	50	yes	n/a	n/a	n/a	80	100	no
UC2.4_AS01 06	100	120	50	yes	120	50	yes	110	150	no	80	100	no
UC2.4_AS01 xxx	Create more test scenarios by iterating the parameters above …												

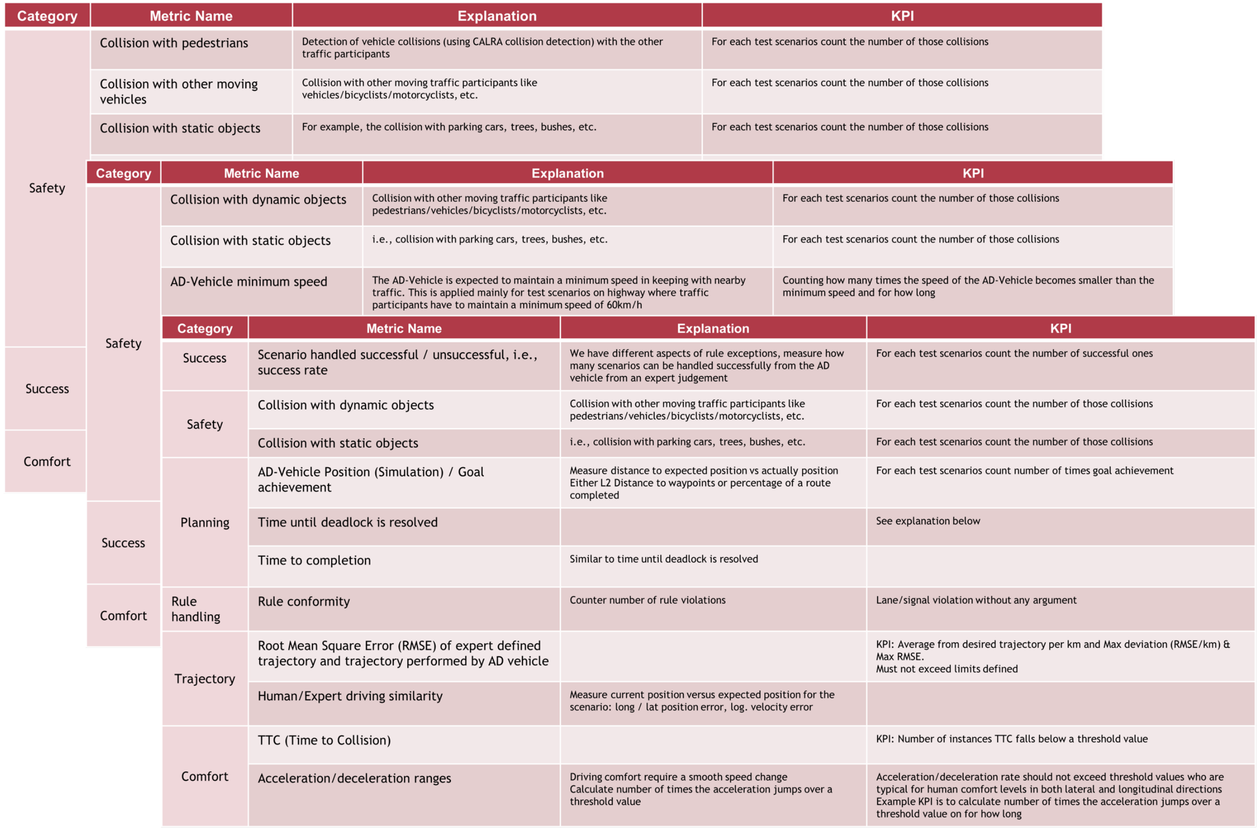
Evaluation Metrics Catalog

A catalog of various metrics was developed which partners could use to evaluate their AI modules:

Common evaluation metrics: module-based and scenario-based metrics

Quality and criticality metrics

System-level metrics for each Use Case



Category	Metric Name	Explanation	KPI
Safety	Collision with pedestrians	Detection of vehicle collisions (using CALRA collision detection) with the other traffic participants	For each test scenarios count the number of those collisions
	Collision with other moving vehicles	Collision with other moving traffic participants like vehicles/bicyclists/motorcyclists, etc.	For each test scenarios count the number of those collisions
	Collision with static objects	For example, the collision with parking cars, trees, bushes, etc.	For each test scenarios count the number of those collisions
Success			
Comfort			

Category	Metric Name	Explanation	KPI
Safety	Collision with dynamic objects	Collision with other moving traffic participants like pedestrians/vehicles/bicyclists/motorcyclists, etc.	For each test scenarios count the number of those collisions
	Collision with static objects	i.e., collision with parking cars, trees, bushes, etc.	For each test scenarios count the number of those collisions
	AD-Vehicle minimum speed	The AD-Vehicle is expected to maintain a minimum speed in keeping with nearby traffic. This is applied mainly for test scenarios on highway where traffic participants have to maintain a minimum speed of 60km/h	Counting how many times the speed of the AD-Vehicle becomes smaller than the minimum speed and for how long
Success			
Comfort			

Category	Metric Name	Explanation	KPI
Success	Scenario handled successful / unsuccessful, i.e., success rate	We have different aspects of rule exceptions, measure how many scenarios can be handled successfully from the AD vehicle from an expert judgement	For each test scenarios count the number of successful ones
Safety	Collision with dynamic objects	Collision with other moving traffic participants like pedestrians/vehicles/bicyclists/motorcyclists, etc.	For each test scenarios count the number of those collisions
	Collision with static objects	i.e., collision with parking cars, trees, bushes, etc.	For each test scenarios count the number of those collisions
Planning	AD-Vehicle Position (Simulation) / Goal achievement	Measure distance to expected position vs actually position Either L2 Distance to waypoints or percentage of a route completed	For each test scenarios count number of times goal achievement
	Time until deadlock is resolved		See explanation below
	Time to completion	Similar to time until deadlock is resolved	
Rule handling	Rule conformity	Counter number of rule violations	Lane/signal violation without any argument
Trajectory	Root Mean Square Error (RMSE) of expert defined trajectory and trajectory performed by AD vehicle		KPI: Average from desired trajectory per km and Max deviation (RMSE/km) & Max RMSE. Must not exceed limits defined
	Human/Expert driving similarity	Measure current position versus expected position for the scenario: long / lat position error, log. velocity error	
Comfort	TTC (Time to Collision)		KPI: Number of instances TTC falls below a threshold value
	Acceleration/deceleration ranges	Driving comfort require a smooth speed change Calculate number of times the acceleration jumps over a threshold value	Acceleration/deceleration rate should not exceed threshold values who are typical for human comfort levels in both lateral and longitudinal directions Example KPI is to calculate number of times the acceleration jumps over a threshold value on for how long

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»» Overall System Concept

Overall System Concept

Requirements

- CI/CD Pipeline
- AD Stack & Simulation Environment
- Interfaces

Selection of Sensors in CARLA Simulator

Definition of ROS Topics

AD-Stack Architecture

Simulation Architecture

TP4 Demonstrator presentation

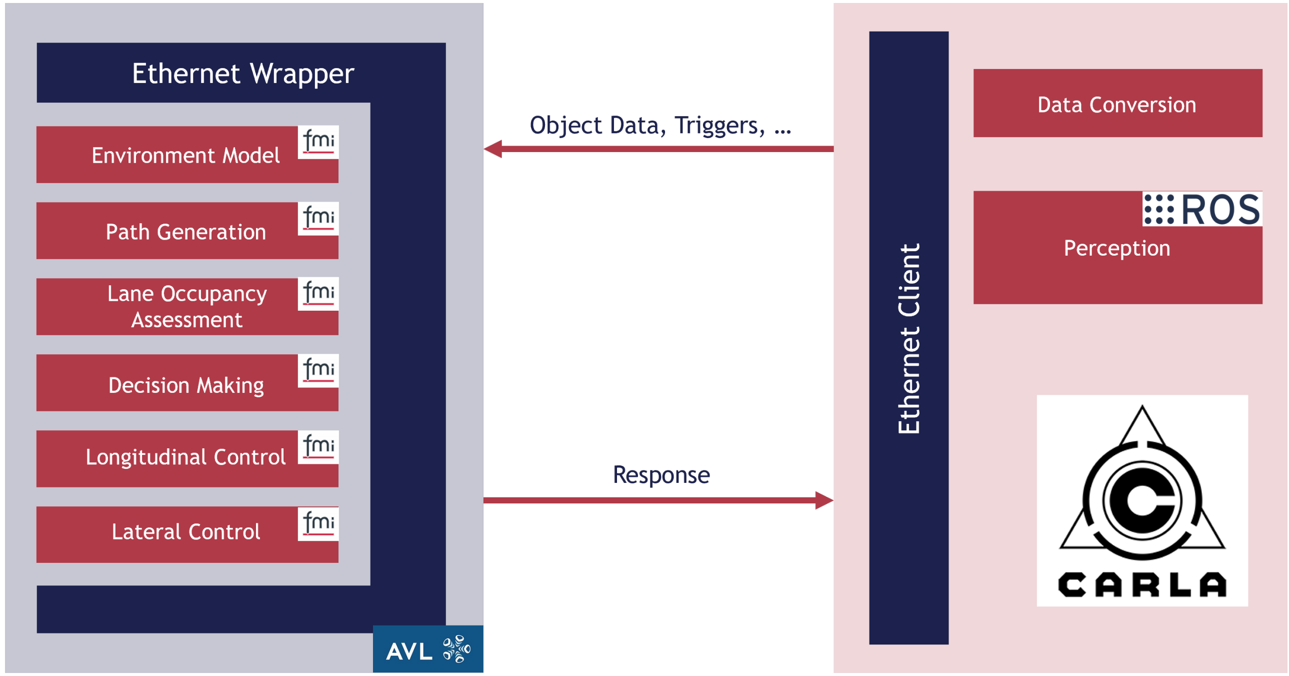
Shared Demonstrator Concept

The TP4 demonstrator operates as a distributed system where the AD Stack is running at AVL side hosted on a basic public server.

AVL provides each of the AD-Stack components (AVL Highway Pilot) as independent FMU's that partners can also replace if needed.

The communication between components happens through ROS messages.

Partners host their simulation environment in their own hardware and interact with the server through an Ethernet Wrapper/Client solution.



Ethernet Wrapper

Environment Model

Path Generation

Lane Occupancy Assessment

Decision Making

Longitudinal Control

Lateral Control

Object Data, Triggers, …

Response

Ethernet Client

Data Conversion

Perception

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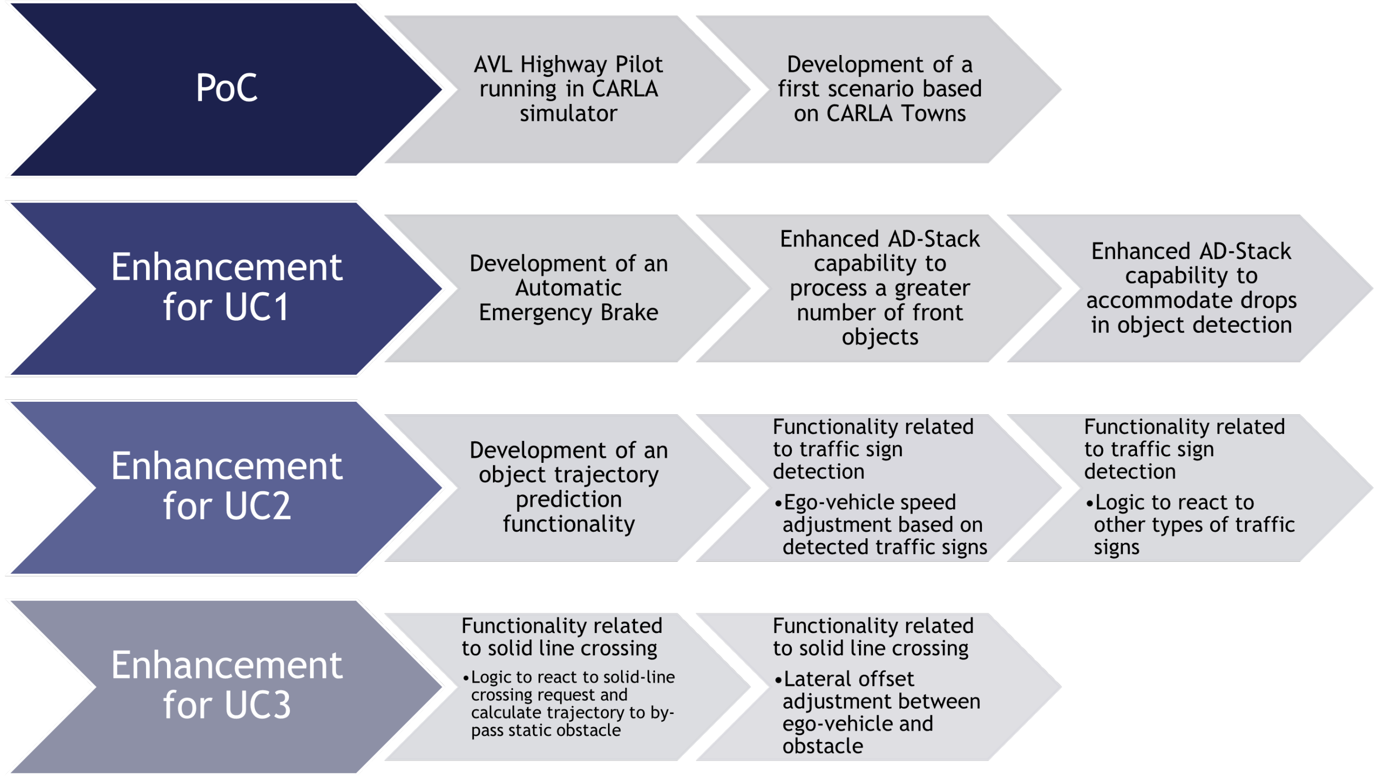
»» Implementation & Integration of AD Stack

Implementation & Integration

Enhancements to the AD Stack:



PoC	AVL Highway Pilot running in CARLA simulator	Development of a first scenario based on CARLA Towns	
Enhancement for UC1	Development of an Automatic Emergency Brake	Enhanced AD-Stack capability to process a greater number of front objects	Enhanced AD-Stack capability to accommodate drops in object detection
Enhancement for UC2	Development of an object trajectory prediction functionality	Functionality related to traffic sign detection •Ego-vehicle speed adjustment based on detected traffic signs	Functionality related to traffic sign detection •Logic to react to other types of traffic signs
Enhancement for UC3	Functionality related to solid line crossing •Logic to react to solid-line crossing request and calculate trajectory to by-pass static obstacle	Functionality related to solid line crossing •Lateral offset adjustment between ego-vehicle and obstacle	

- AVL provided their Highway Pilot, which was further enhanced to allow simulations in each Use Case.
- The AD Stack was developed incrementally to meet new requirements from project partners.
- Each new feature was added one at a time, while ensuring that the stack was fully functional at every iteration.

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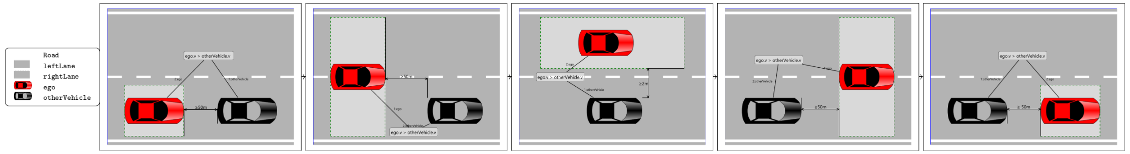
» Generation & Provision of Data Sets

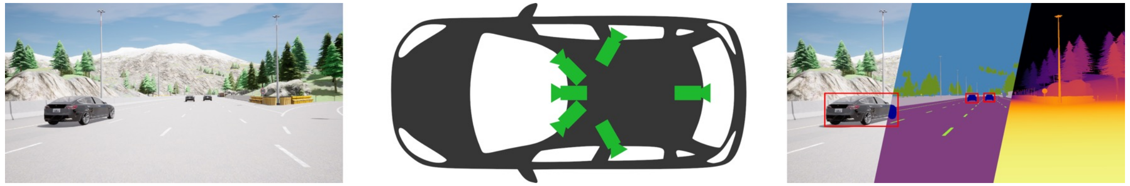
Generation & Provision of Datasets

AVL, Bosch, Continental, DFKI, DLR, and Valeo created several simulation scenarios and scenario variants for the specified Use Cases to run in the CARLA environment.

DLR developed scenario variation methods and generated 300 variations of the UC2.4 scenario using the Traffic Sequence Charts (TSC) scenario description language.

Synthetic data were recorded with a virtual sensor setup and ground truth annotations for 2D/3D bounding boxes, semantic segmentation, instance segmentation, depth estimation and vehicle trajectories.





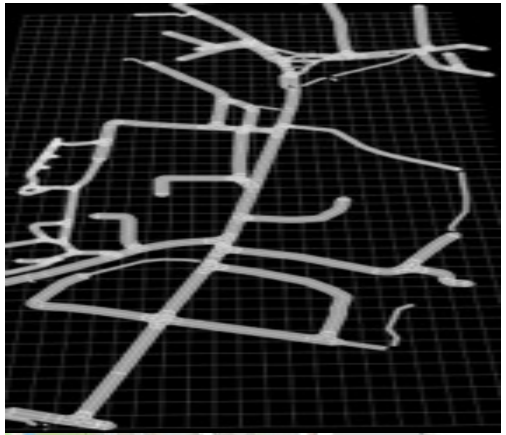
Generation & Provision of Datasets

Real-data Campaign:

- 222 sequences provided by Valeo
- 57 sequences provided by AVL
- 2-hour recording session by FZI
- Valeo and AVL collaborated to extract map data from ASAM OpenStreetMap and convert it to OpenDRIVE (.xodr) format based on the GPS position of their recording cars.
- FZI data feature optional V2X and HD map integration.

Data Labelling:

- Joint subcontracting of Capgemini Outsourcing
- Auto labeling framework and cut-in detection by FZI



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» Evaluation & Demonstration

Evaluation & Demonstration

Alexander Thamm - Conformity Check for Pedestrian Detection

- Integrating approaches from TP3 into the Carla demonstrator.
- Image region-based conformity check (AP3.1).
- K-nearest-neighbors based conformity check (AP3.2).
- Evaluation in CARLA against baseline models.
- Development of the scene duration system level metric.

Evaluation & Demonstration

AVL - Knowledge Conformity for Pedestrian Detection

- Method to merge outputs from Physical and World knowledge module into a single plausibility score.
- The final output reduces False Positives without reducing the True Positive rate (TPR).
- Tested the method on real data (nuScenes [1]) and CARLA simulated dataset (UC1).
- The results shows improved average precision across all the scenarios.

[1] Holger Caesar et al. “nuScenes: A multimodal dataset for autonomous driving”. In: arXiv preprint arXiv:1903.11027 (2019)

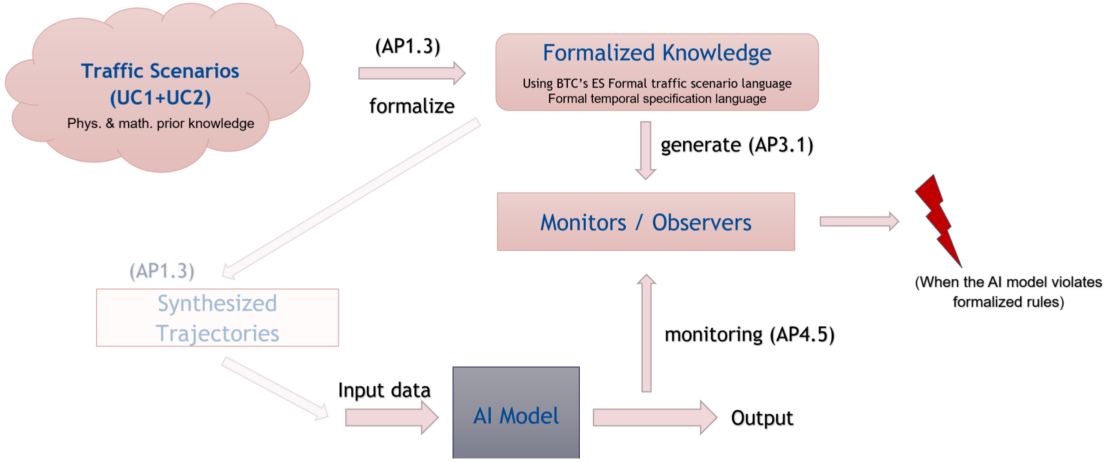
1.5

Poster

Evaluation & Demonstration

BTC:ES - Formalized Knowledge of Traffic Dynamics

- Formalization of physical and mathematical knowledge of traffic scenarios using Formal Traffic Scenario (FTS), BTC's formal language.
- Generation of monitors (observers) from formalized scenarios.
- The observers take a trajectory of the ego vehicle recorded during the simulation as input.
- The observers then check whether the ego vehicle behaves in accordance with the expected behavior which was formalized with FTS.
- The observer can detect violations of the expected behavior of the ego vehicle.



Traffic Scenarios (UC1+UC2)
Phys. & math. prior knowledge

(AP1.3)
formalize

Formalized Knowledge
Using BTC's ES Formal traffic scenario language
Formal temporal specification language

generate (AP3.1)

Monitors / Observers

(When the AI model violates formalized rules)

(AP1.3)
Synthesized Trajectories

monitoring (AP4.5)

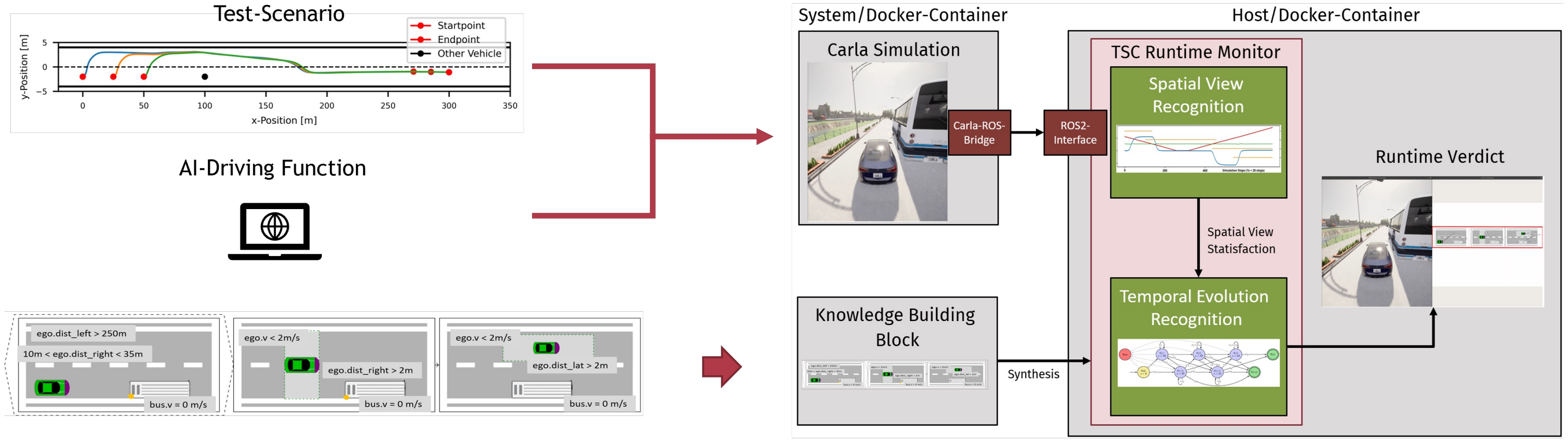
Input data

AI Model

Output

Evaluation & Demonstration

DLR e.V. - Runtime Monitoring for Multi-Stakeholder Knowledge Specified as Traffic Sequence Charts



Multi-Stakeholder Knowledge Specification

Runtime Monitoring for Knowledge Conformity

- Runtime monitoring based on the visual yet formal Traffic Sequence Charts specification language.
- Monitor from TP3 is integrated into a CARLA simulation to check knowledge conformance in simulation runs.

- Implemented a metric for checking accelerating and decelerating rates in UC1.

7
Highlight

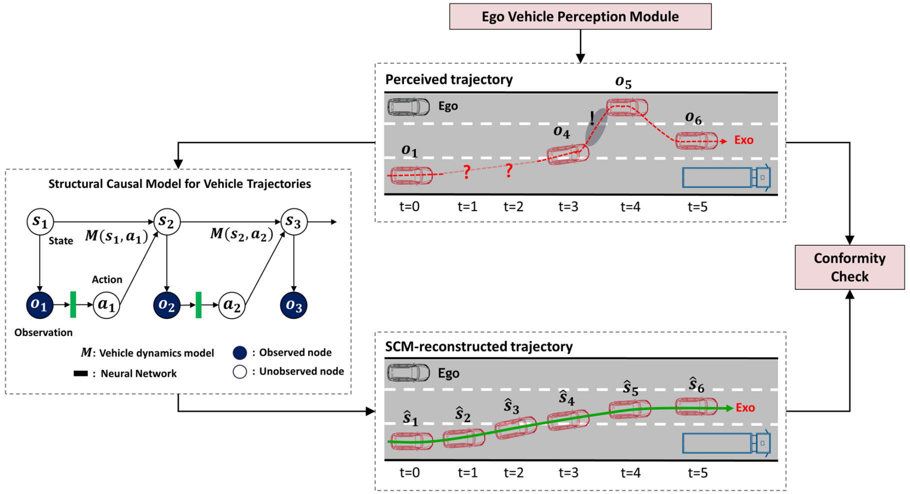
3.12
Poster

3.9
Poster

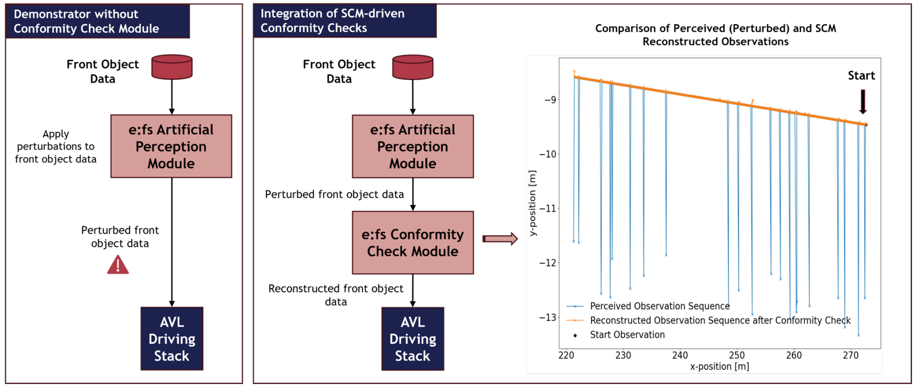
Evaluation & Demonstration

e:fs - Causality-driven Conformity Checks of Vehicle Trajectories

- Objective: detection and correction of physically unreasonable vehicle trajectories.
- Concept (AP 3.1): Structural Causal Model (SCM) used for conformity checks [1].
- Integration of SCM-driven conformity check methods in the TP4 demonstrator.



Concept for conformity checking of vehicle trajectories (© e:fs TechHub GmbH, adapted from [1])


Demonstrator without Conformity Check Module

Front Object Data

Apply perturbations to front object data

e:fs Artificial Perception Module

Perturbed front object data

AVL Driving Stack

Integration of SCM-driven Conformity Checks

Front Object Data

e:fs Artificial Perception Module

Perturbed front object data

e:fs Conformity Check Module

Reconstructed front object data

AVL Driving Stack

Presentation

[1] H. Agarwal, C. Brunner, et.al, "A Causal Model for Physics-Conform Vehicle Trajectories," 2023 IEEE 26th International Conference on Intelligent Transportation Systems (ITSC), Bilbao, Spain, 2023, pp. 4980-4987.

5 Highlight

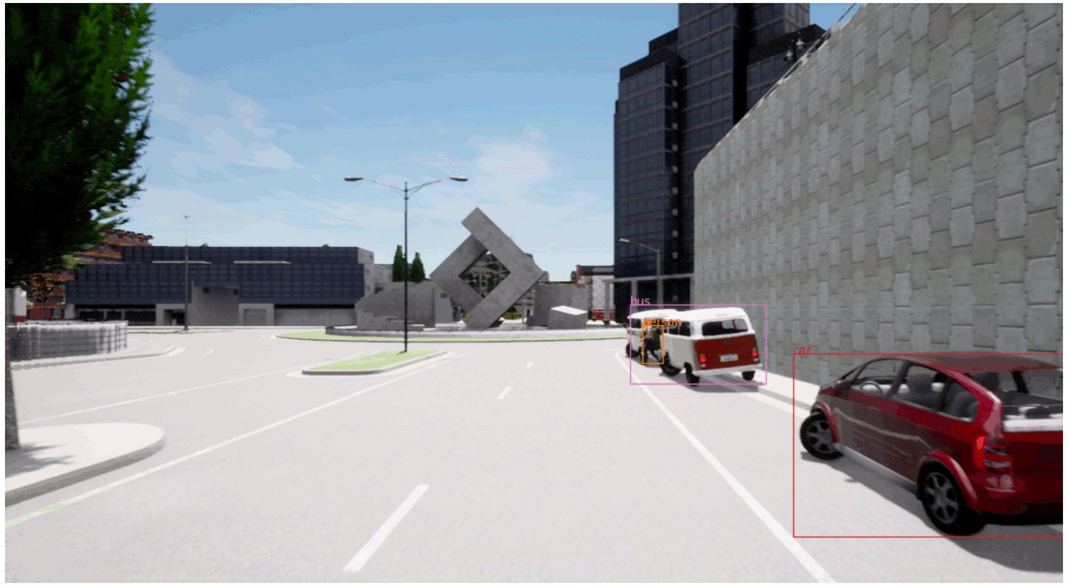
2.6 Poster

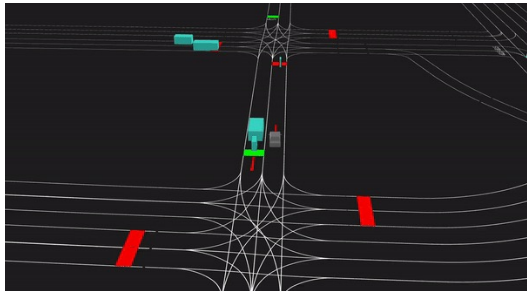
2.7 Poster

Evaluation & Demonstration

FORTISS - Pedestrian Detection & Motion Planning

- Transformer-based detector successfully detects occluded pedestrians upon their appearance (Town03 UC1.2).
- Bidirectional BARK - CARLA Co-Simulation:
  - OpenSCENARIO CARLA -> BARK
  - Bark generated scenarios -> CARLA
- Neural motion planner interacts directly with CARLA, visualized with CARLA Viz.
- Additional evaluation of detection approaches based on publicly available real-world datasets.



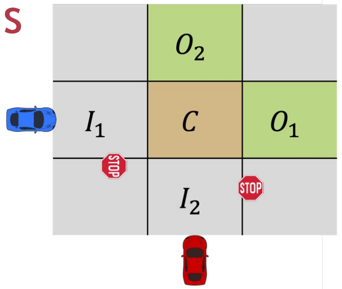


4 Highlight | **3.11** Poster | **1.6** Poster | **1.1** Poster

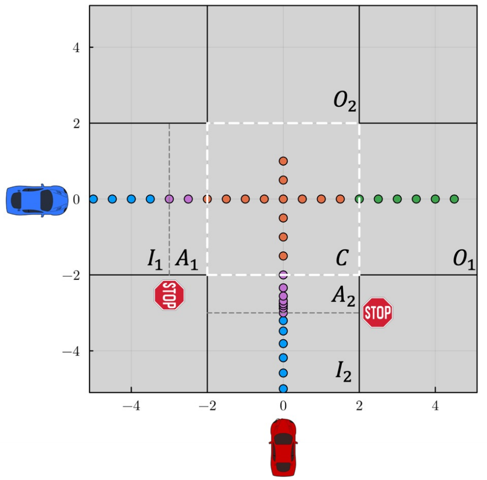
Evaluation & Demonstration

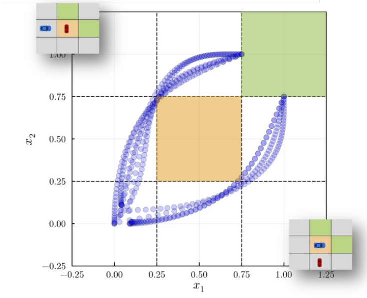
FZI-MPS - Motion Planning under Temporal Logic Specifications

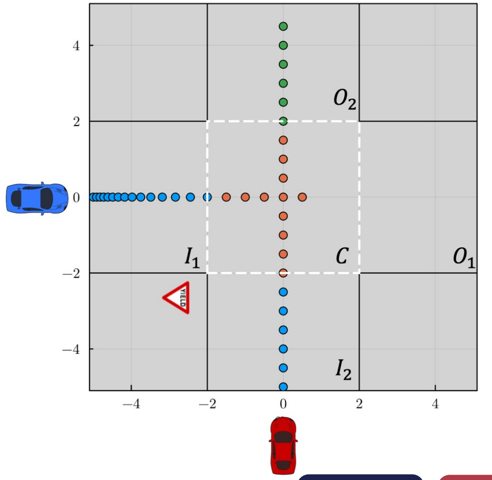
- Modelling and controlling of vehicle motion at urban intersections with continuous agent dynamics and temporal logic constraints.
- Convert the temporal logic rules to Büchi automata and control using mixed integer programming.



$$G\neg(x_1 \in C \wedge x_2 \in C) \\ \wedge F(x_1 \in O_1) \\ \wedge F(x_2 \in O_2)$$







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Highlight

2.10
Poster

Evaluation & Demonstration

Bosch	3.6 Poster	
Capgemini	2.10 Poster	2 Highlight
DFKI	3 Highlight	

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KI Wissen is a project of the KI Familie. It was initiated and developed by the VDA Leitinitiative autonomous and connected driving and is funded by the Federal Ministry for Economic Affairs and Climate Action.

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