

Domain model based derivation of virtual driving scenarios for vehicle simulations from in-field measurements

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Agenda

- Motivation
- Concept for scenario abstraction
- Proposed modelling approach
- Prototype implementation
- Conclusion & future work

The 10^9 mile issue – How to validate automated vehicles?

Real world testing



- Test cases are always valid
- Highly expensive
- Can be dangerous
- Poorly reproducible

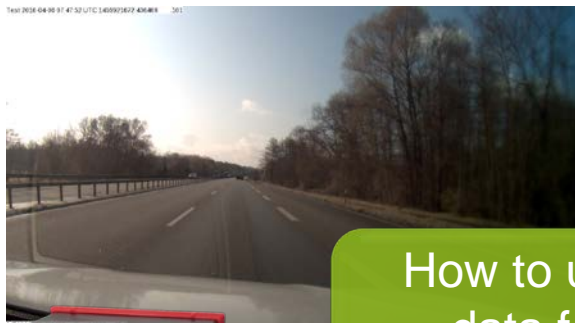
Simulation based testing



- Reproducibility is ensured
- Initially expensive
- Needs validation
- Which variations are interesting?

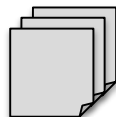
Development of automotive systems and software

Real World Driving Test

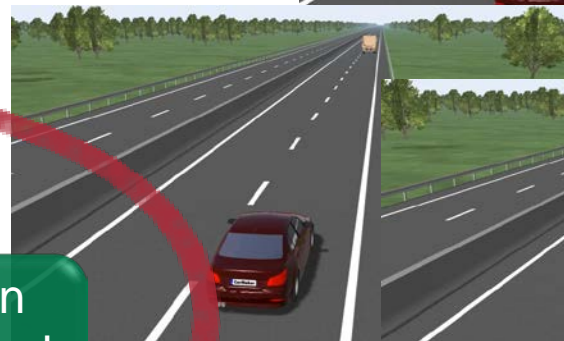


Data logging device

Direct replay with **open-loop** behavior

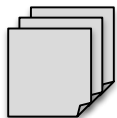


Reactive simulation environment



How to use recorded data for test and simulation?

Abstraction and resimulation with **closed-loop** behavior and optional variations



Abstraction of an ACC-Approach-and-Follow Scenario

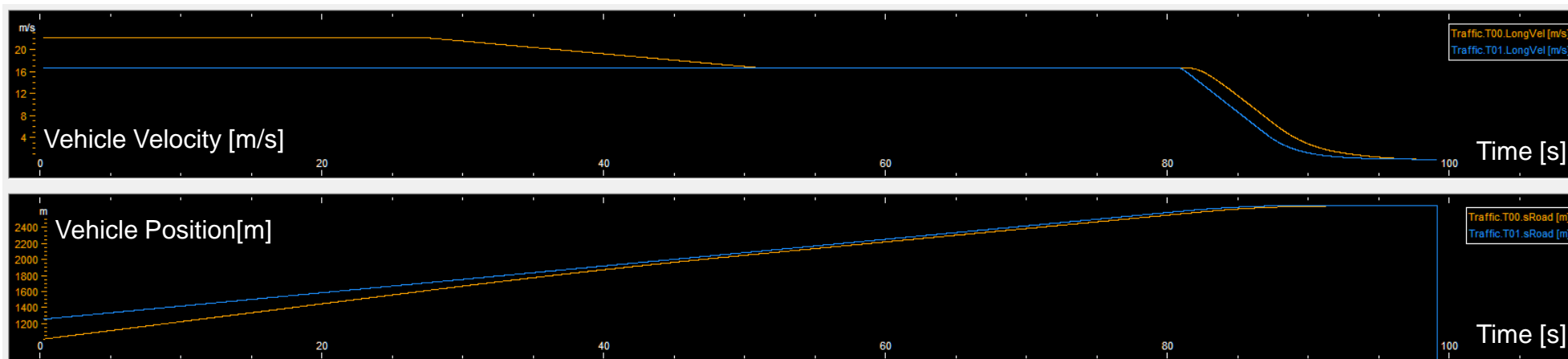
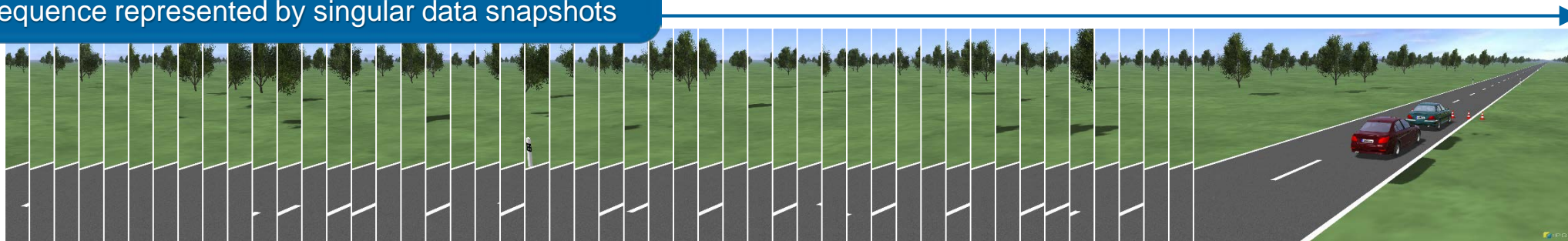


ACC-Approach-and-Follow
Approaching a slower moving lead vehicle
and slowing down to follow by distinct
time-gap

Abstraction of an ACC-Approach-and-Follow Scenario

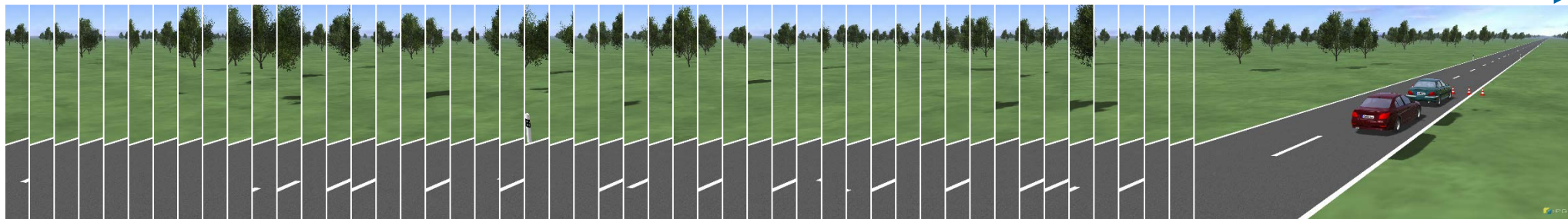
Discrete recording

Temporal synchronous recording of a driving sequence represented by singular data snapshots



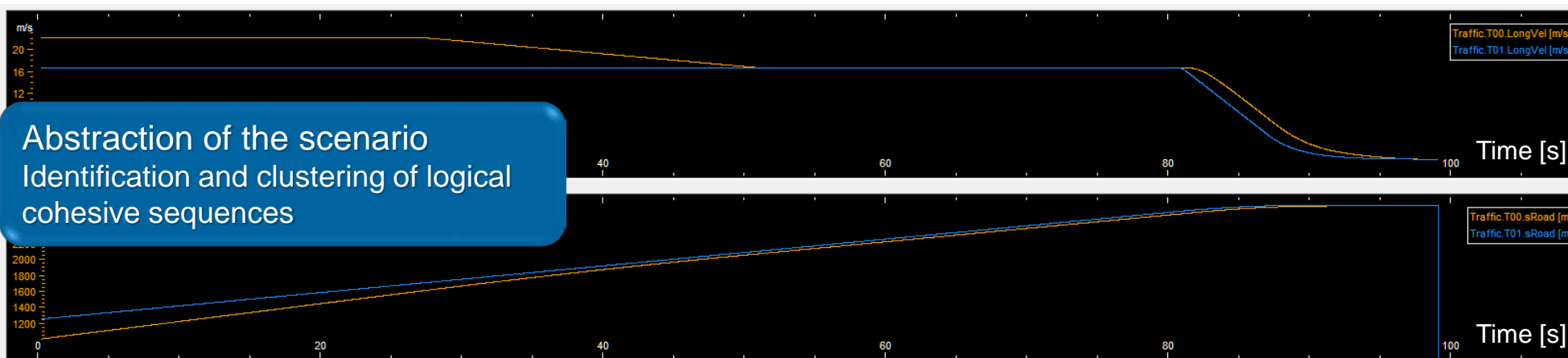
Abstraction of an ACC-Approach-and-Follow Scenario

Time-based sequence of snapshots



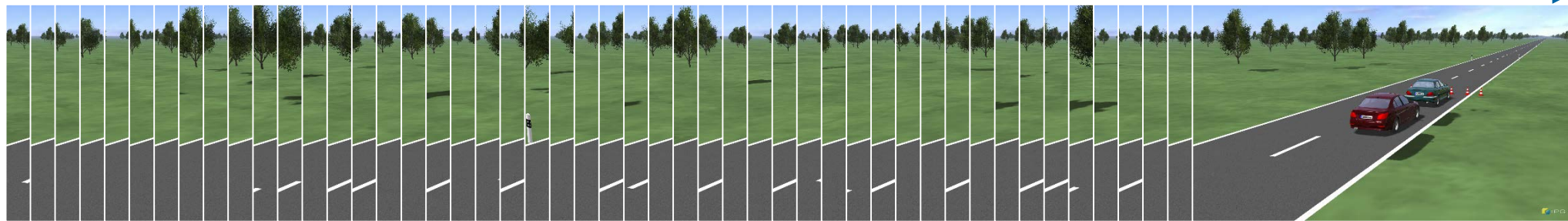
Abstraction

Abstraction of the scenario
Identification and clustering of logical
cohesive sequences

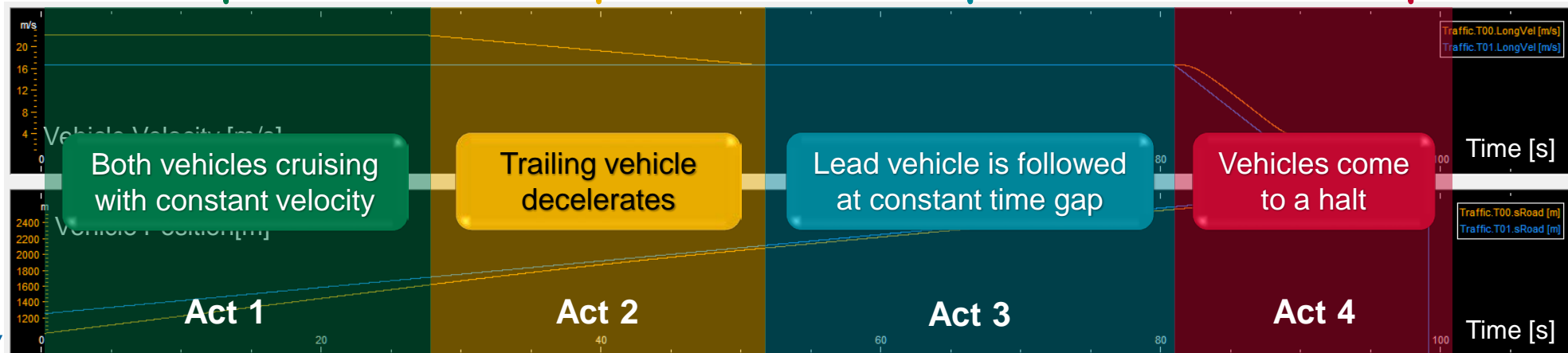


Abstraction of an ACC-Approach-and-Follow Scenario

Time-based sequence of snapshots



Abstraction



Free Cruise
Free Cruise

Approach
Free Cruise

Follow
Free Cruise

Follow
Stop

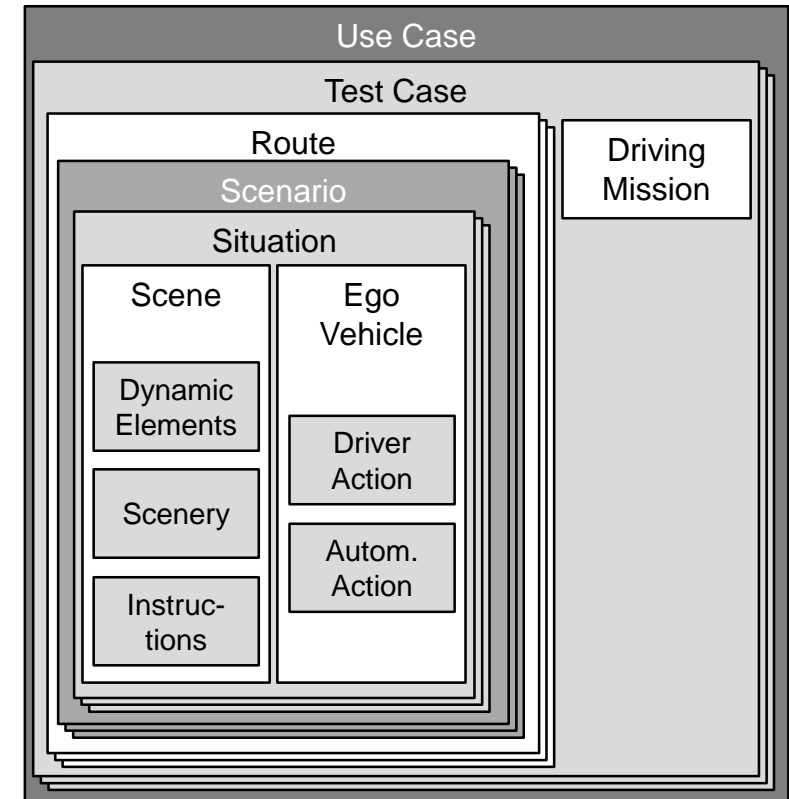
Trailing vehicle
Lead vehicle

Sequence of abstract acts with non-varying driving maneuvers

Main entities of the domain model

Geyer et al propose a **movie and theatre related terminology**

S. Geyer, M. Baltzer, B. Franz, S. Hakuli, M. Kauer, M. Kienle, S. Meier, T. Weißgerber, K. Bengler, R. Bruder, F. Flemisch, and H. Winner, "Concept and development of a unified ontology for generating test and use-case catalogues for assisted and automated vehicle guidance," IET Intelligent Transport Systems, vol. 8, no. 3, pp. 183–189, 2014.



Main entities of the domain model

Scenario

- Postulated development of events
- Encompasses a static scenery

Act

- Grouping of similar snapshots
- Temporal abstraction by sequencing

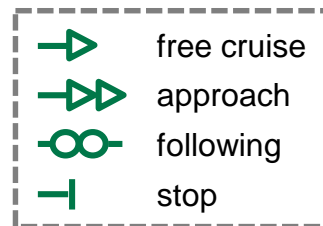
Participants

- Spatial abstraction by perception and interaction layers



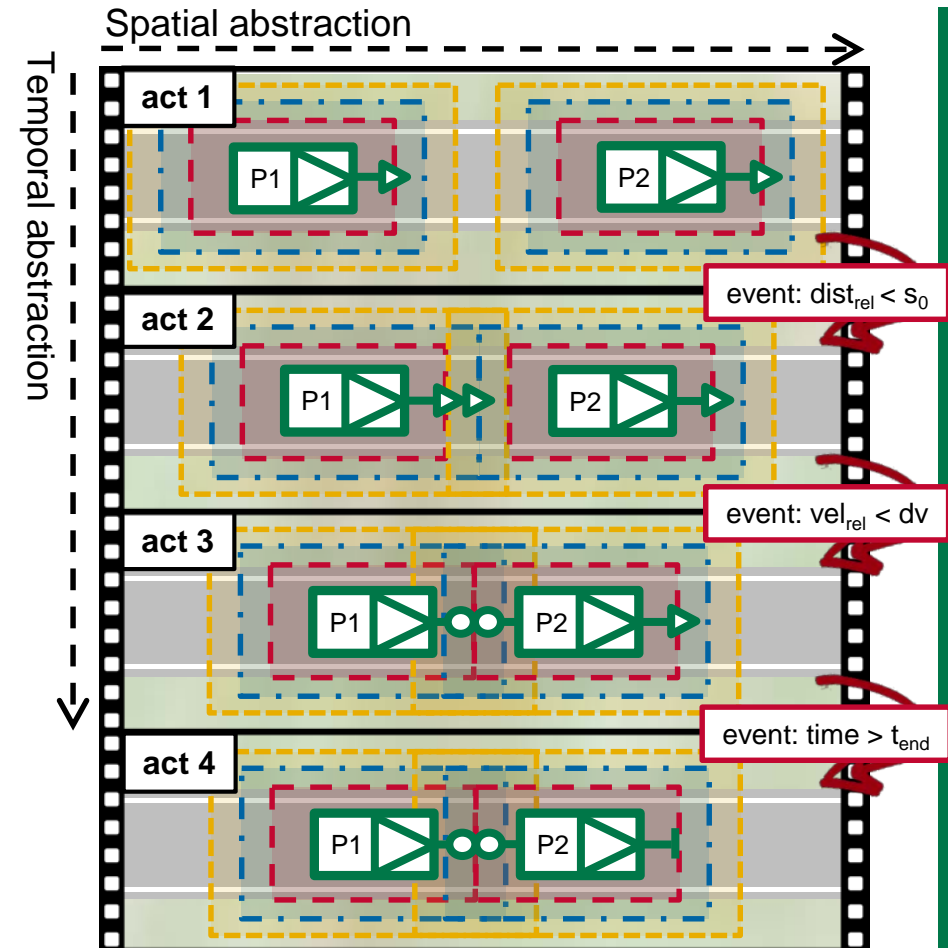
Maneuver

- Behavior abstraction by maneuver types
- One maneuver transition per act



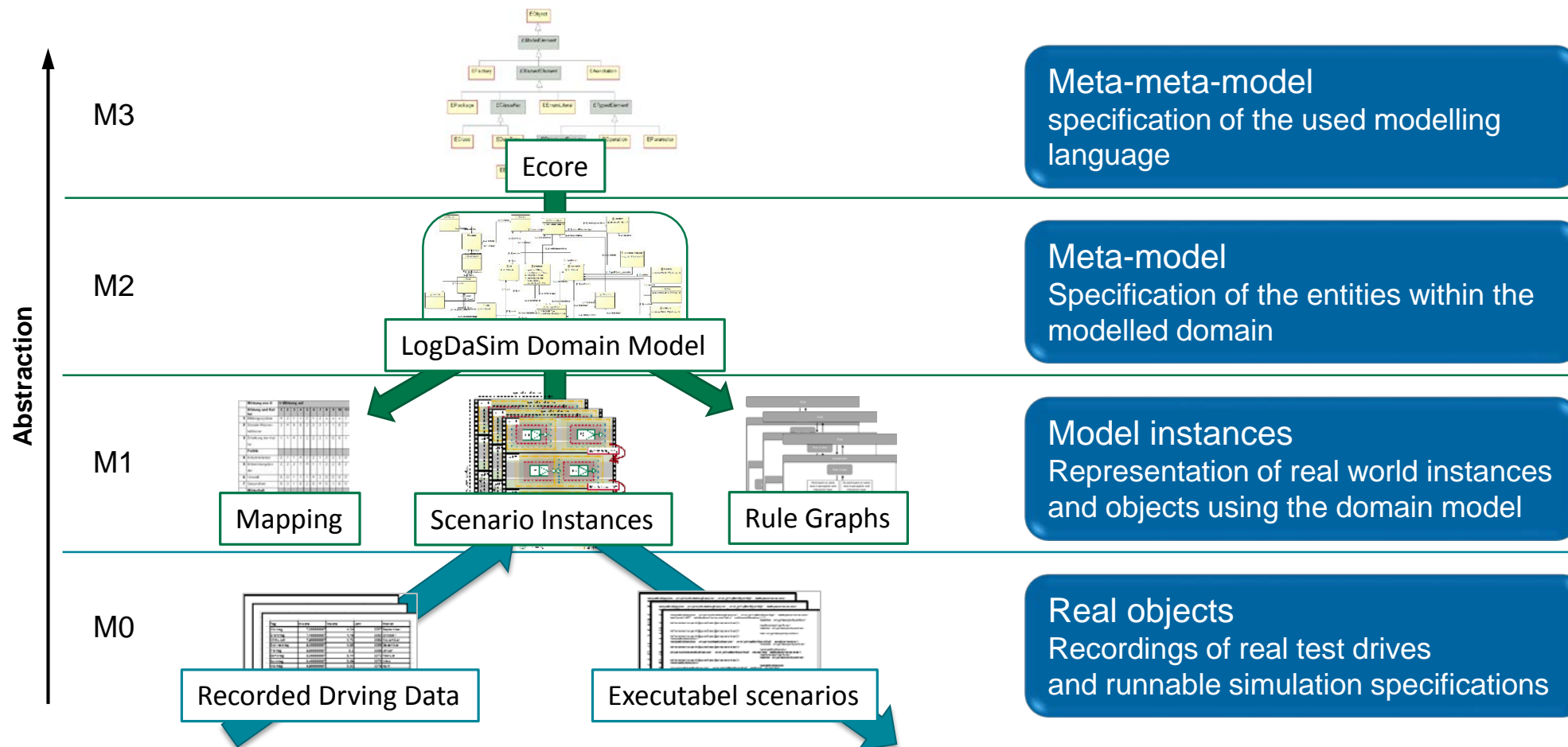
Events

- Specify the exact maneuver transition
- All events are based on relative relations to other participants or the state at the start of the act



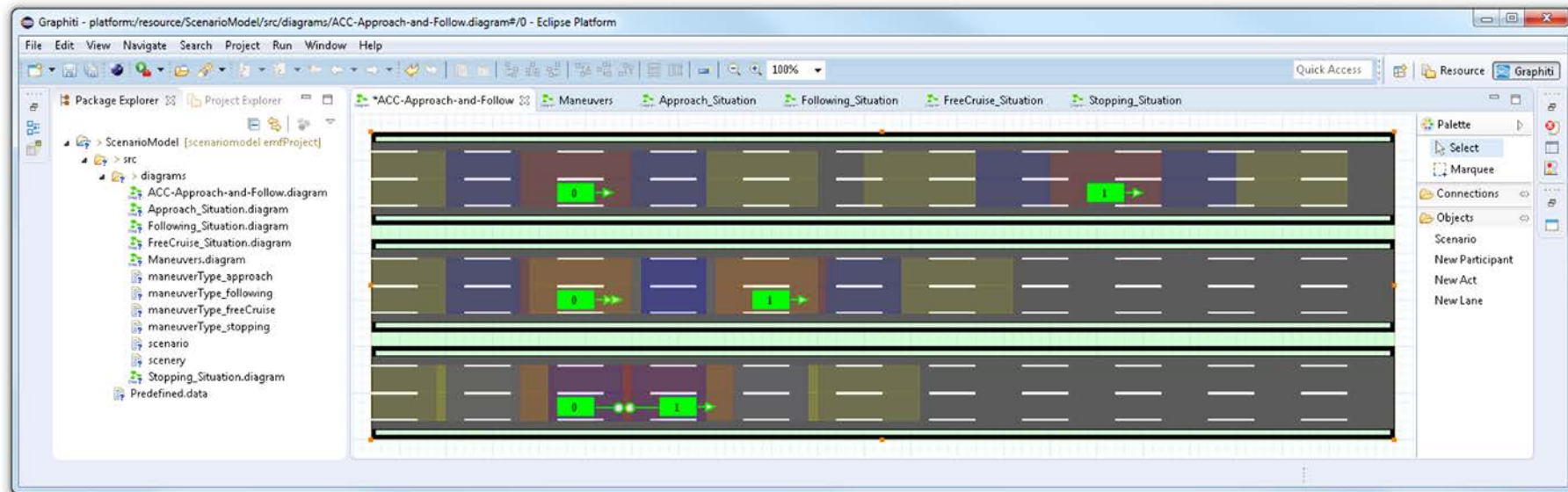
Modeling approach

4 layer approach based on Eclipse Ecore



Prototype scenario editor

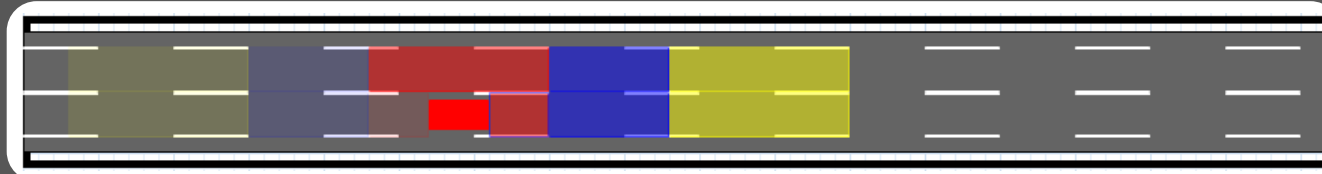
- Specification of act based scenarios
- Import of recorded data
- Export of derived simulation scenarios
- Modelling of maneuver types based on situations



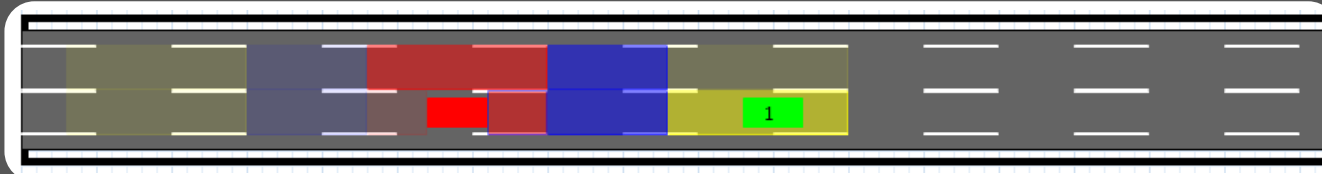
Prototype scenario editor

- Abstract specification of maneuver types based on logic-level situations
 - Spatial abstract conditions by perception layers
 - Relative relations between participant's states for situational specification

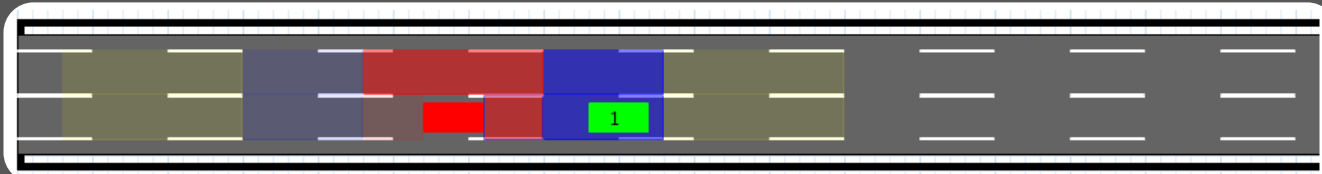
Free-Cruise
Empty lane in front and left
of ego-vehicle



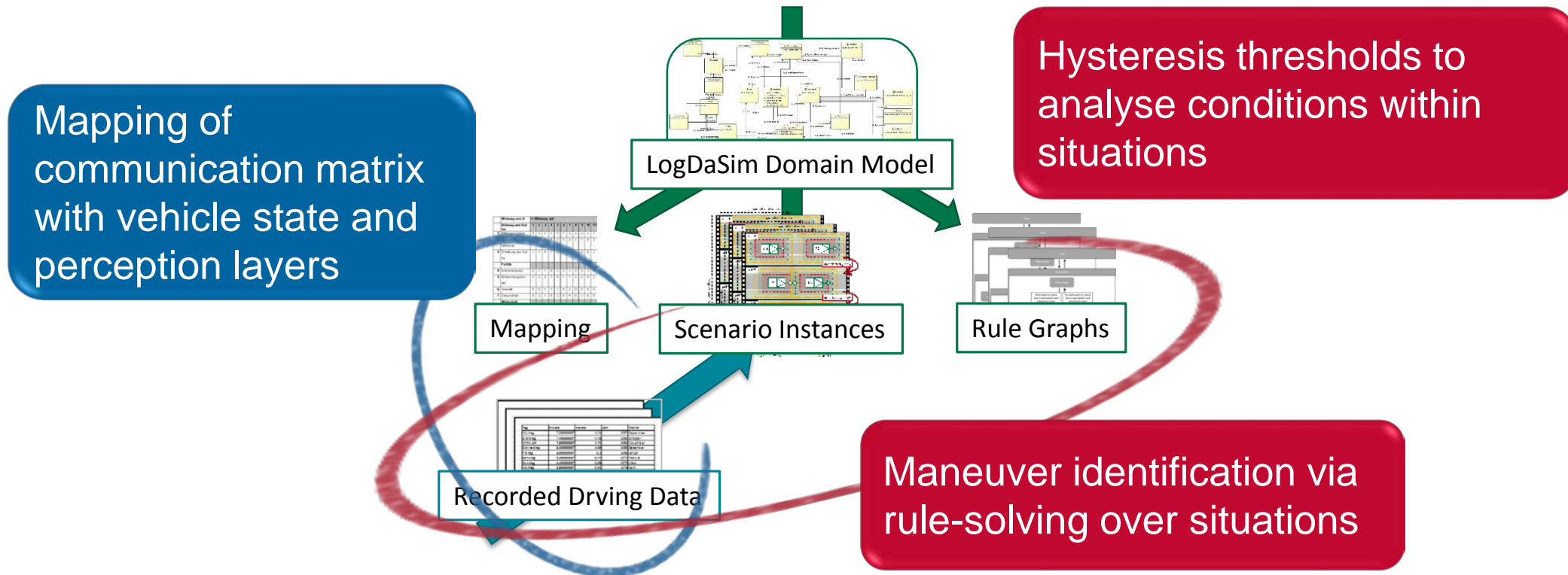
Approach
Preceding vehicle with
 $V_1 < V_{Ego}$



Follow
Preceding vehicle with
 $V_1 \sim V_{Ego}$



Import of recorded data

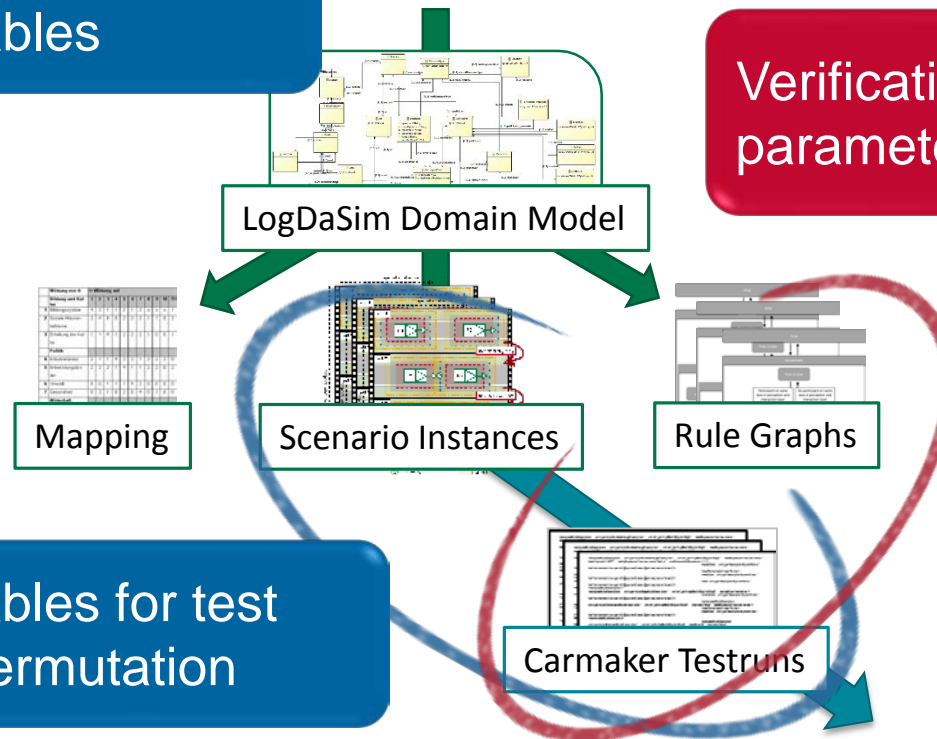


Export of derived simulation scenarios

Substantiation by Parametrization
of physical event variables

Verification by evaluation of
parameters on logical level

Substitute variables for test
variation and permutation

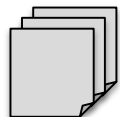


Conclusion and future work

Real world driving data



Data logging device

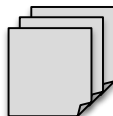


Abstraction of recorded data



Specification of scenario filters

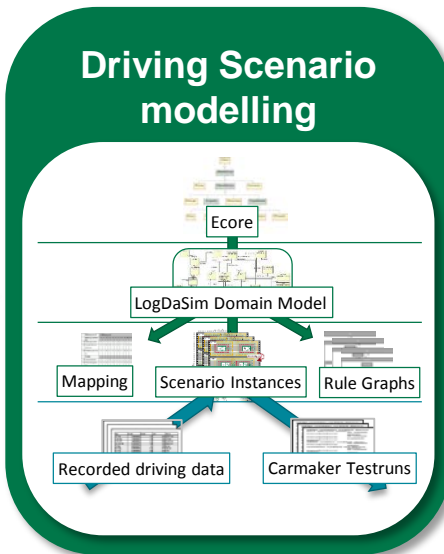
Direct usage for open-loop replay



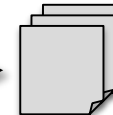
Reactive simulation environment



Driving Scenario modelling



Parametrable scenarios



uses

Generation



Tests

Conclusion and future work

CONCLUSION

- Concept for consistent spatial, temporal and behavioral abstraction
- Feasibility proven with approach-and-follow scenario
- Scenario Import from measurements possible
- Generation of permutable simulation scenarios

NEXT STEPS

- Evaluations with multi-participant scenarios
- Definition and evaluation of further maneuver types
- Integration of static scenery elements as reference points

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GEFÖRDERT VOM



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