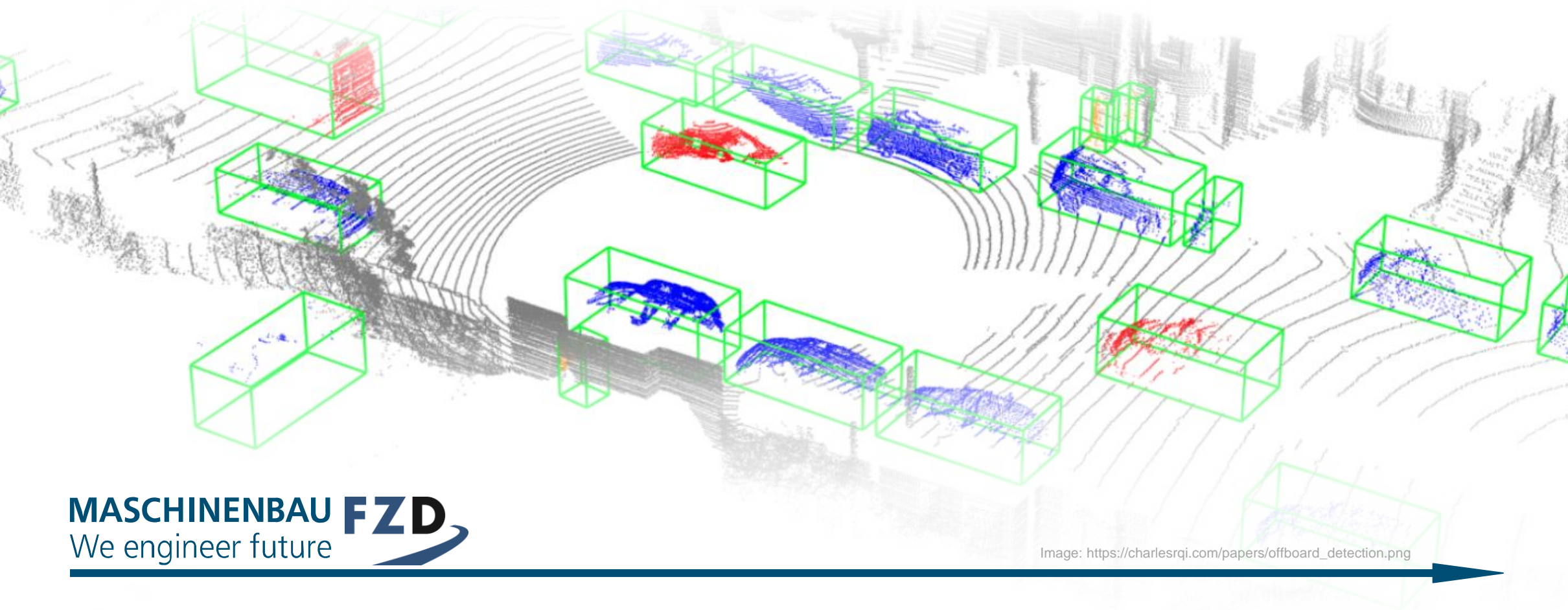


Conservative Perception Relevance of Dynamic Objects



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Motivation

Automated driving

- Safety assurance
- Typical Sense-Plan-Act architecture
- Modular evaluation/validation
- Act requirements are specified

Open questions

- How to consider driving safety for perception?
- What does not need to be perceived?

→ What makes an object irrelevant?

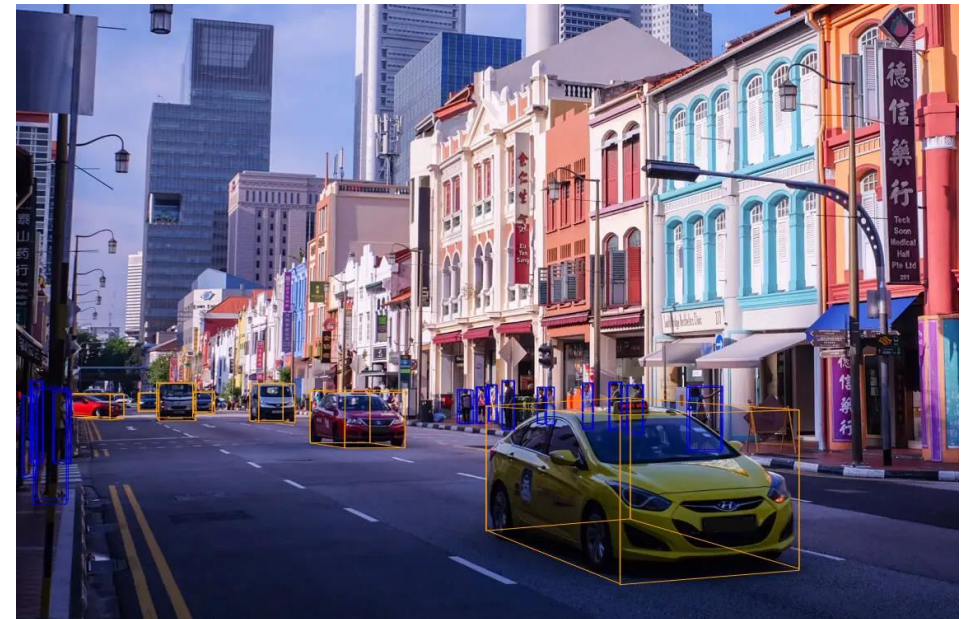


Image: <https://www.nuscenes.org/static/media/road-750h.c22d47a4.webp>

Related Work

Perception evaluation with datasets

- Relevance implicitly determined by inclusion in ground truth
- Inclusion based on arbitrary criteria
 - Geometric criteria
 - Human perception on sensor data



Relevance in Planning

- Relevance implicitly determined by input to neural planners
 - Geometric criteria
 - Predetermined number of objects
- Formal planners explicitly consider relevance
 - Consider behavior not perception

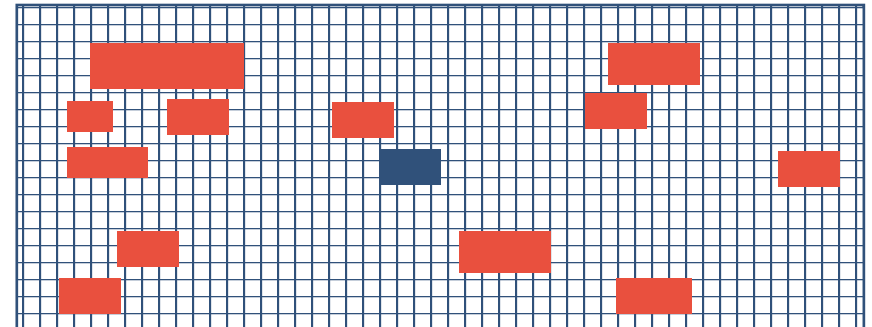


Image: https://www.highd-dataset.com/static/img/titelvideo_MomentHighD.5174a14.png

Related Work

Relevance for Perception Evaluation

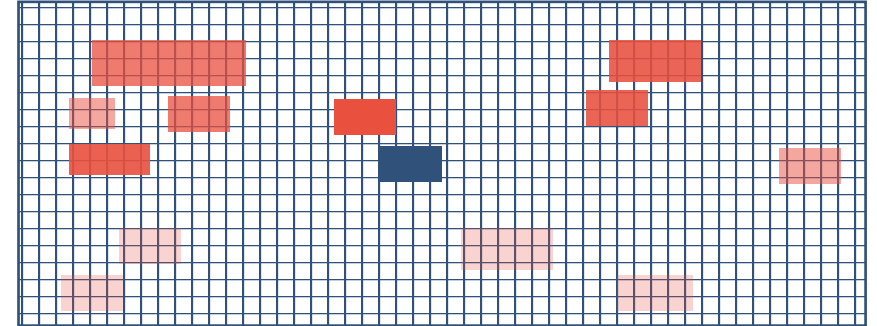
- Concrete implementation of planner
 - Restricted to single specific implementation
- General specifications with formal planner
 - Transfer to perception unsubstantiated

Assumptions

- Stopping is valid behavior
- Ego intention available
- Road environment information available

Limitations

- Structured procedure unavailable
- Lack of specification not addressed



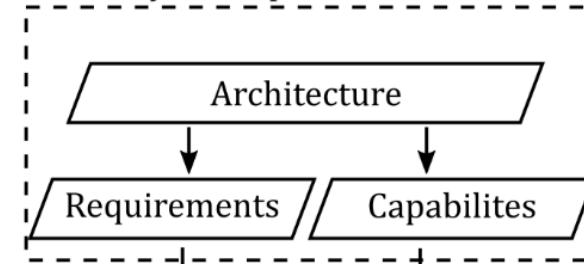
- **Specify minimum system**
 - Object list as Sense/Plan interface
 - R1) Obey traffic rules! C1) React in time
 - R2) Do not collide! C2) Steer/Accelerate
- **Specify use case**
 - Highway
- **Decompose**
- **Identify behavioral requirements for scenarios**

REQ2.1: *The ego vehicle shall be able to brake to halt behind a vehicle in front to avoid a collision in the event that the front car suddenly brakes.*

- **Formalize requirements into equation**

$$0 < d_{\min} = d_0 - s_1 - s_2 + \frac{v_{1,x,0}^2}{2a_{\max}} - v_{2,x,0} t_{2,x} - \frac{1}{2} a_{\max} t_{2,x}^2 - \frac{(v_{2,x,0} + t_{2,x} a_{\max})^2}{2a_{2,x,b}} \quad (17)$$

Partial System Specification



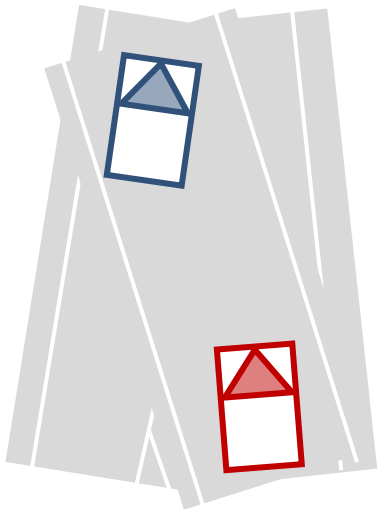
Methodology



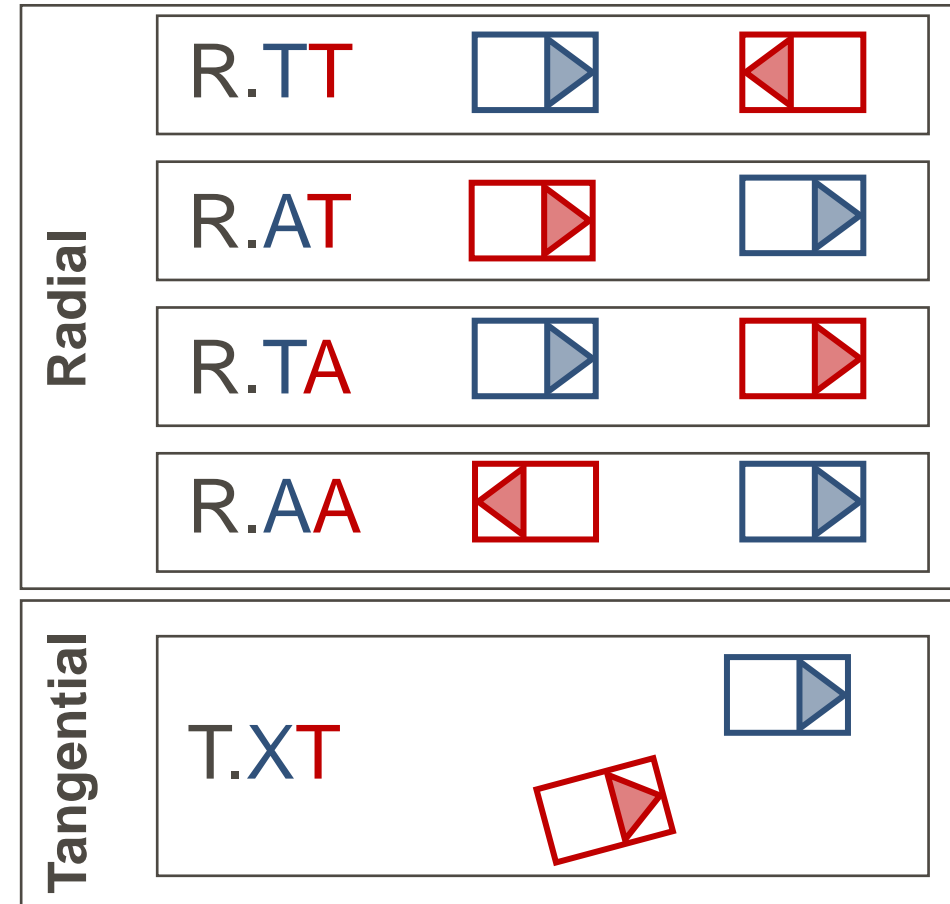
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Use Case Decomposition

- Distinguishing Scenarios
- Radial-Tangential
- Pairwise Interaction
- Superposition Principle



Highway



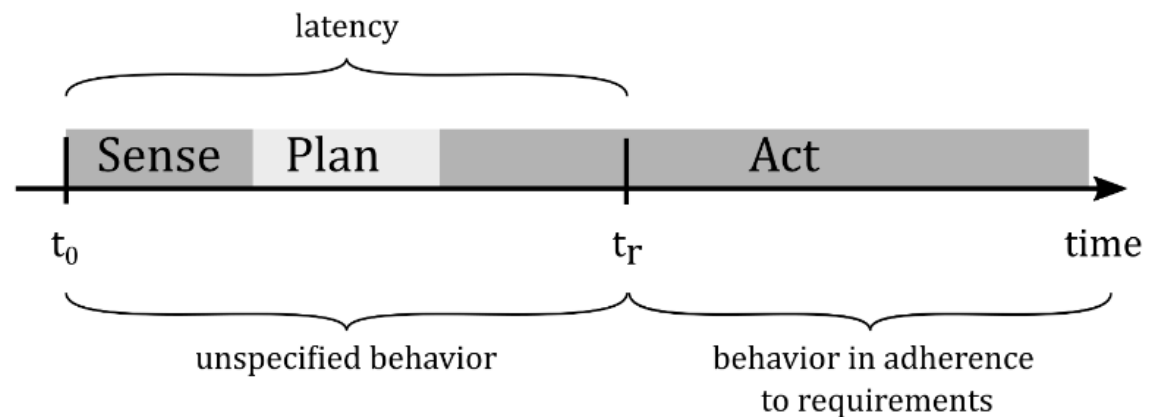
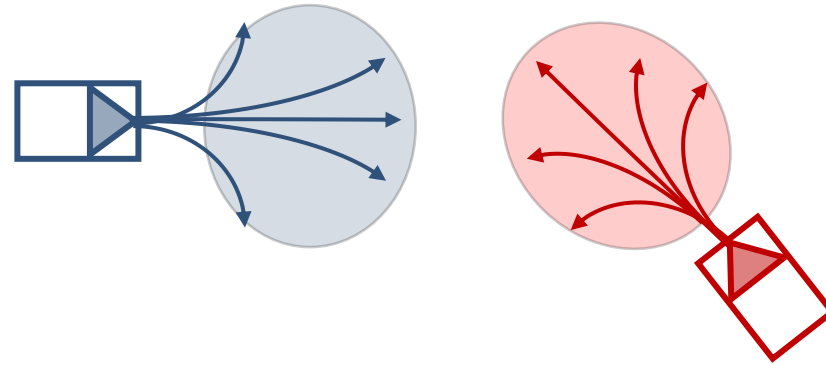
Requirement Formalization

- **Goals**

- Closed form solution
- Minimum scenario knowledge required
 - No road
 - No ego/object intentions

- **Principles**

- (1) Always assume the worst case
- (2) If worst case is implausible
introduce variable as contract



Method Application: Functional Scenario



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Disambiguation

- Radial scenario, ego moving towards, other vehicle moving away: R.TA

Legal Requirement

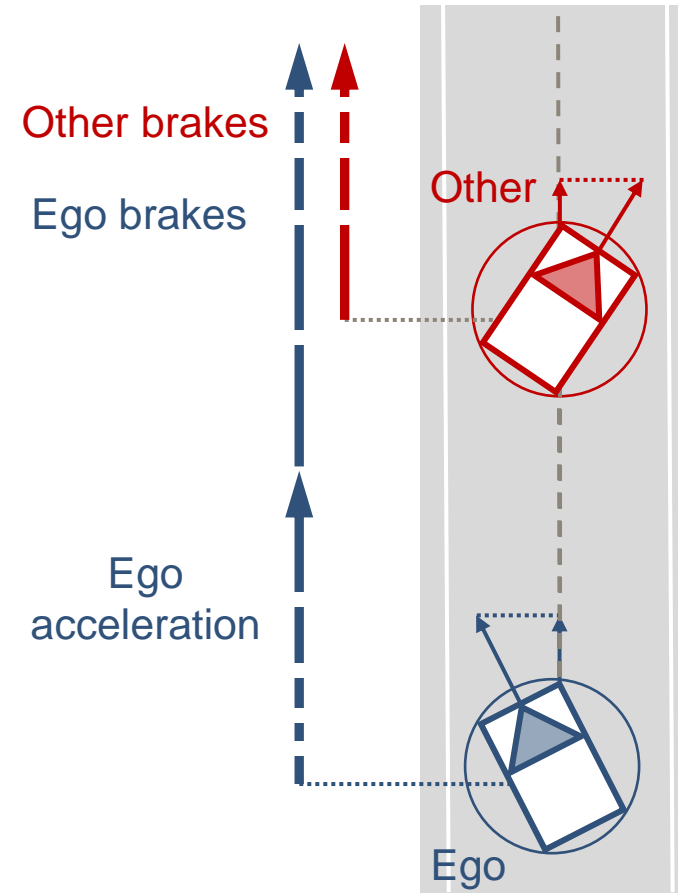
- Avoid collision if front vehicle brakes

Simplified model for hypothetical scenario

- Conservative one-dimensional model
- Worst case behavior of other vehicle
- Worst case behavior of ego during reaction time
- Appropriate response of ego

Develop equation

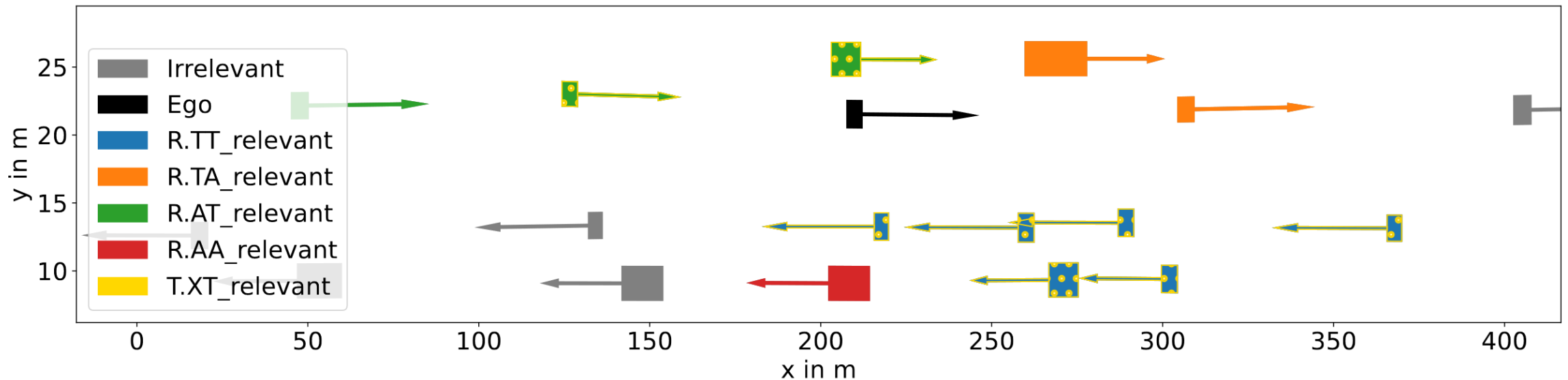
- If equation is violated the object is relevant



Results: HighD example

Real highway data recorded by drone

- Relevance for each functional scenario
- Superposition of scenario relevance visible



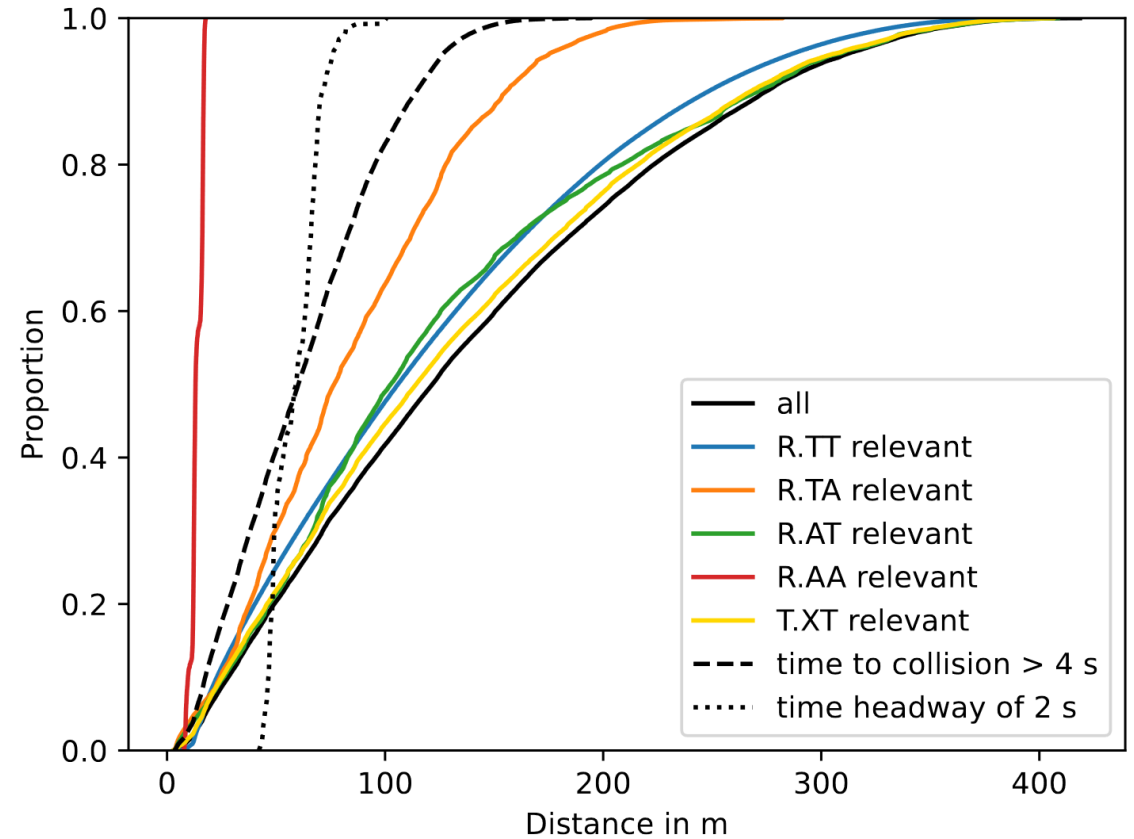
Results & Discussion: HighD Overall

Results

- Empirical cumulative distribution function (ECDF)
- Relevant objects per scenario over distance
- Large distances considered relevant
- Relevant distance is scenario-dependant

Discussion

- Generally more conservative than headway or TTC
- Avoids false negatives, false positives likely



Discussion

Generalization capability

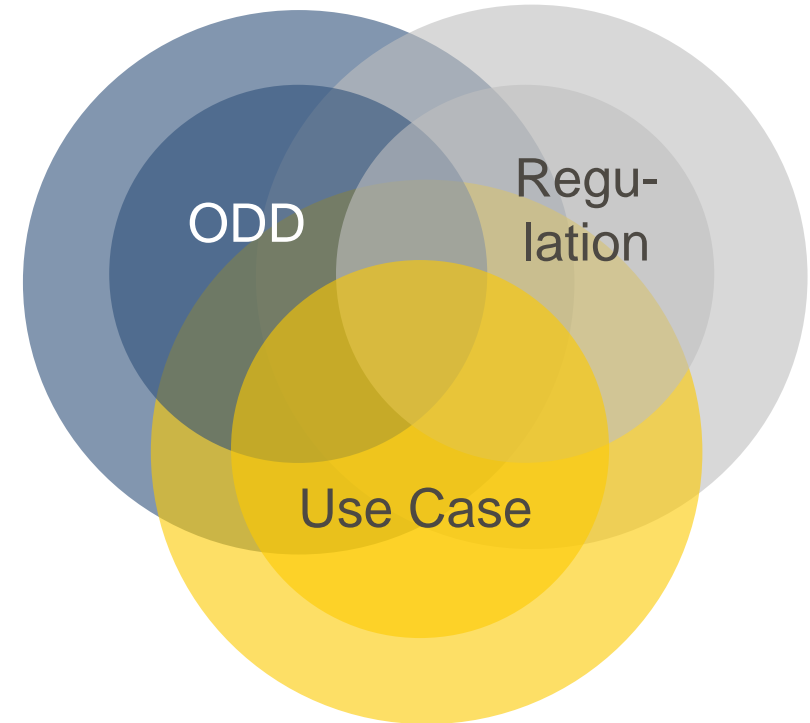
- Other operational design domains
- Road regulations from other countries
- Different use cases

Implications for perception testing

- Distance for relevance is scenario dependent
- Large distances for highway domain

Validation

- Difficult due to lack of established methods



Conclusion & Outlook

Contributions

- Structured approach to determine object relevance
- Specification of the system
- Decomposition of ODD into scenarios
- Equations for relevant objects for each functional scenario
- Application to collision avoidance in highway domain

Outlook

- Expand application
- Validation

