SURE-Val:

Safe **U**rban **R**elevance **E**xtension and **Val**idation

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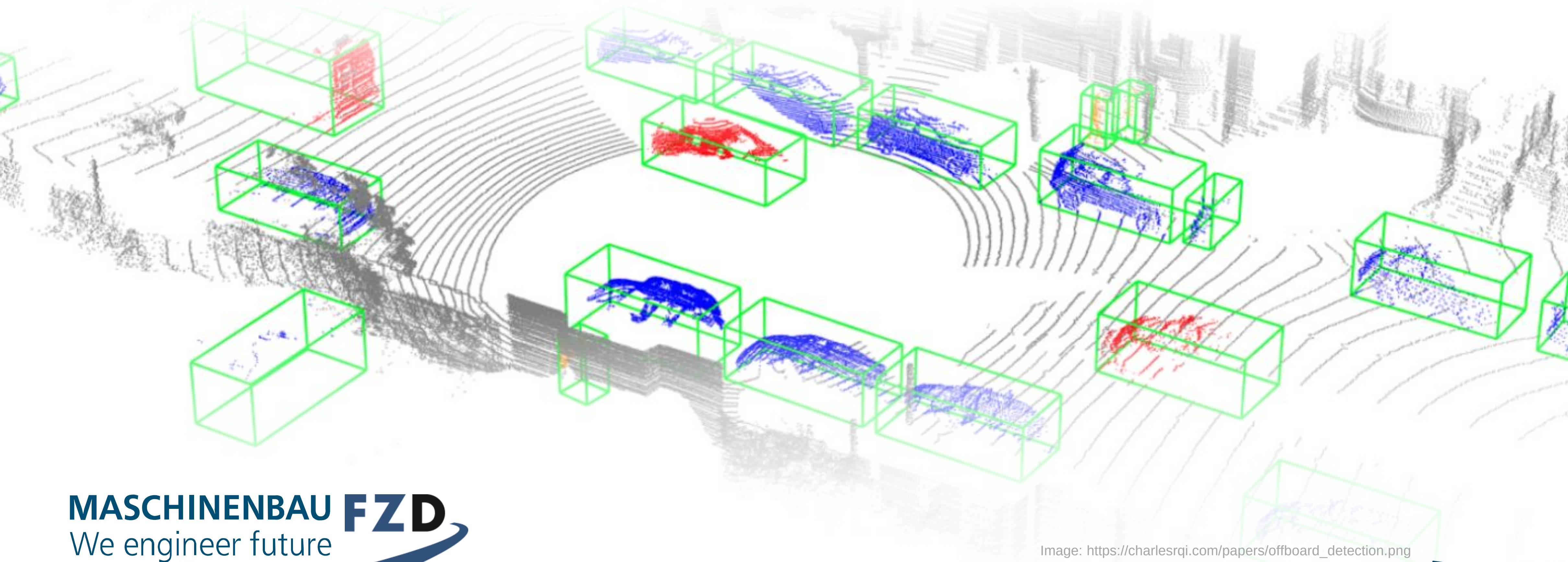

Image: https://charlesrqi.com/papers/offboard_detection.png

MASCHINENBAU
We engineer future
FZD

Motivation

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Automated driving

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

Sense → Plan → Act

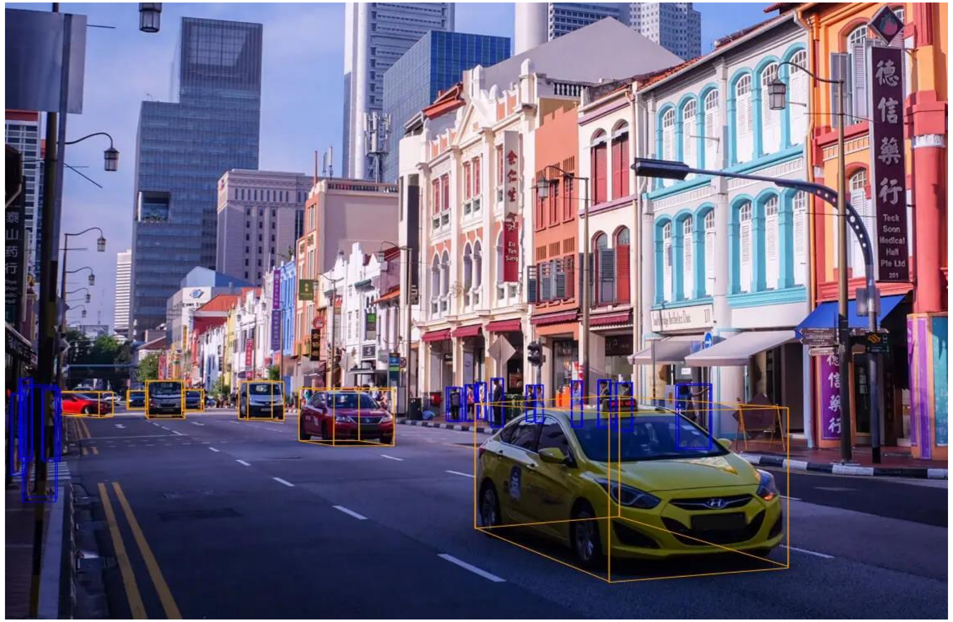


Image: https://www.nuscenes.org/static/media/road-750h.c22d47a4.webp

Open questions

- How to define relevance for automated driving?
- How to validate relevance?

→ **How to know we have a valid model for relevance?**

Related Work: Relevance

Heuristics

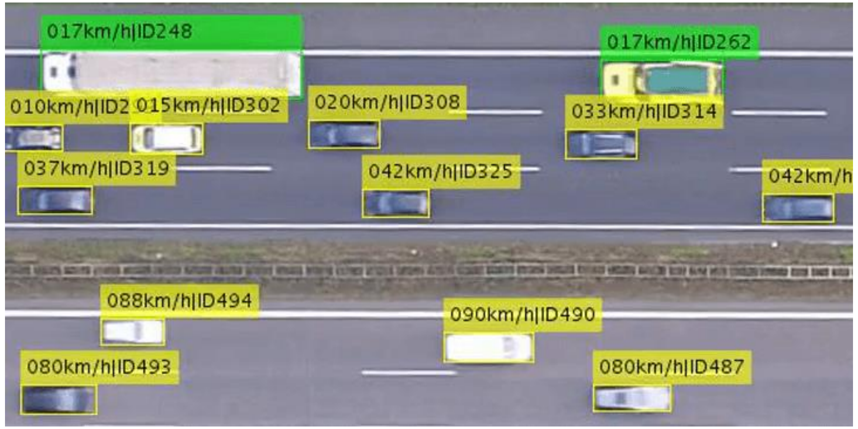
- Arbitrary criteria
- Geometric criteria
- Human perception on sensor data

Formal Approaches

- Formal specification of driving task

Planner Based

- Relevance as downstream impact
- Neural planner lacks interpretability and validity



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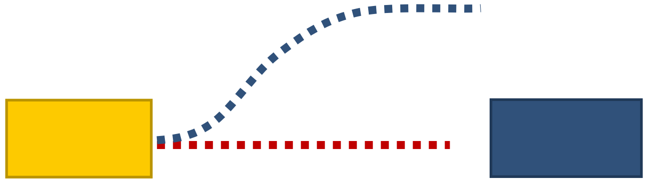

→ Different incompatible methods

Related Work: Validation

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Problems

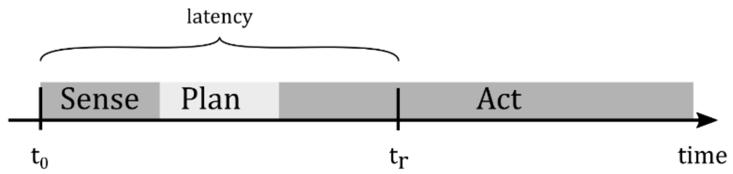
- Incompatible approaches and results
- Validation methods insufficient and lack of validity
- Planner based restricted to single implementation
- Transfer from formal specification to perception

State of the Art

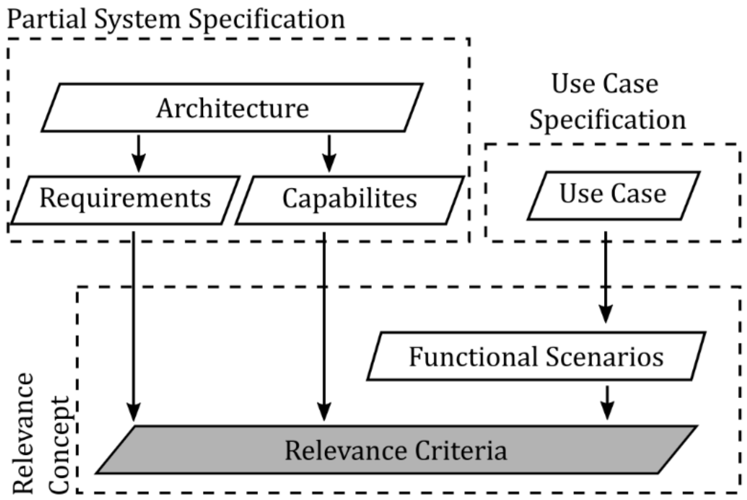
- No validation methods available
- Validation of planners challenging

Relevance Concept

- **Goals**
  - Conservative estimate for object detection relevance
  - Closed form solution
  - Minimum assumptions about scenario
    - No road
    - No ego/object intentions
- **Principles**
  - (1) Always assume the worst case
  - (2) If worst case is implausible
    introduce variable as contract



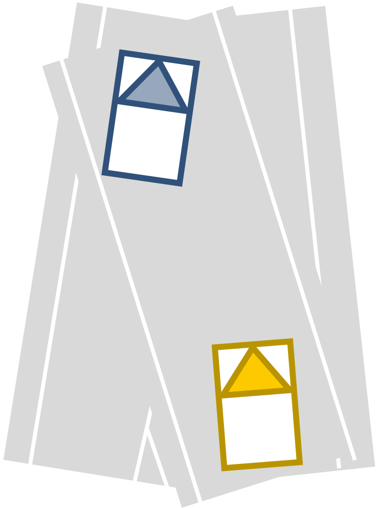
- **Formal Approach**
  - Specify minimum system
  - Specify use case
  - Decompose into functional scenarios
  - Identify behavioral requirements

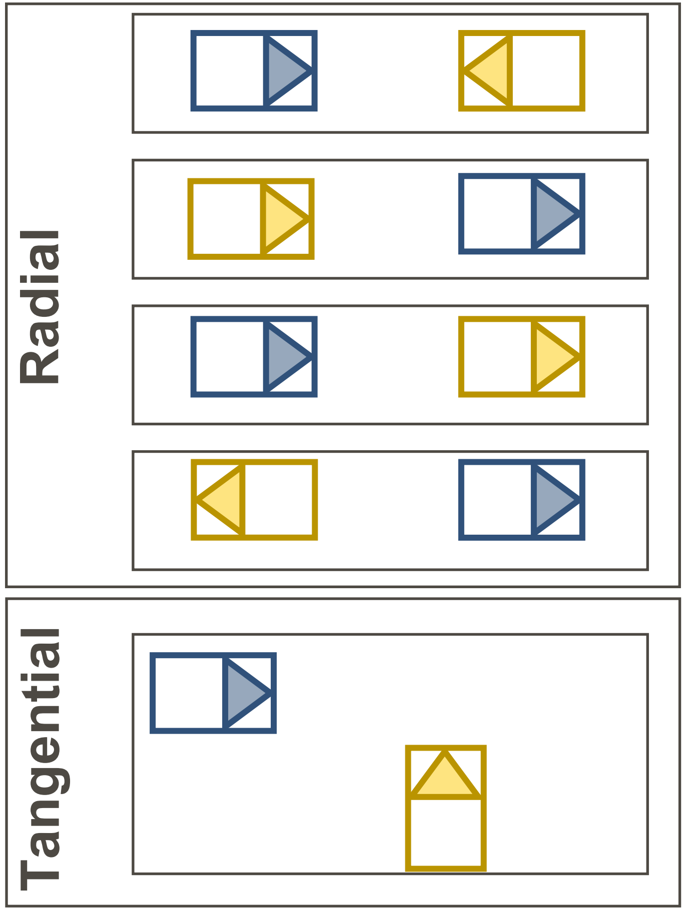


Relevance Concept

Use Case Decomposition

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





Validation: Methodology I

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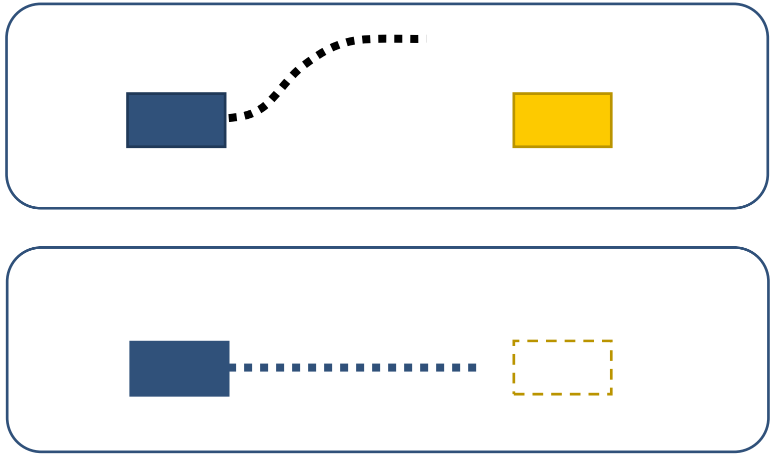
Prior validation

- No methodology available
- Argumentations and planner-based approaches not reconciled

Proposed method

- Interpretable relevance with argumentation
- Motion Prediction DNN
  - Proxy for human behavior
  - Performance can be validated
  - Open-loop and offline evaluation
- Analyze impact of removing objects
  - Correct relevance should not impact prediction



Validation: Methodology II

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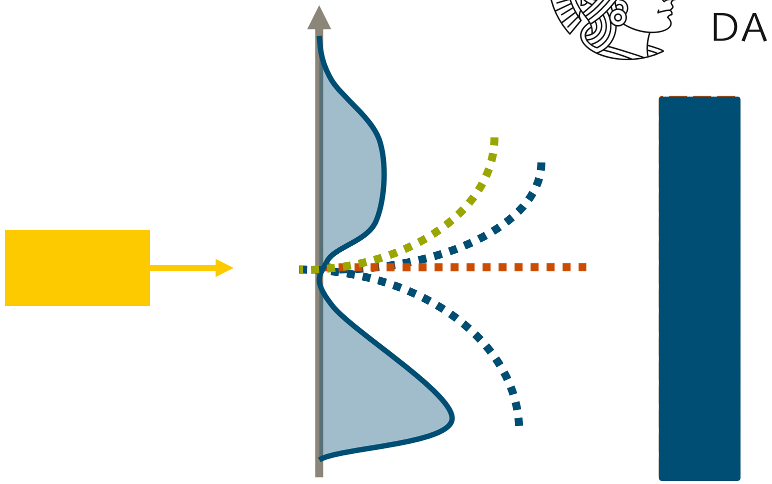
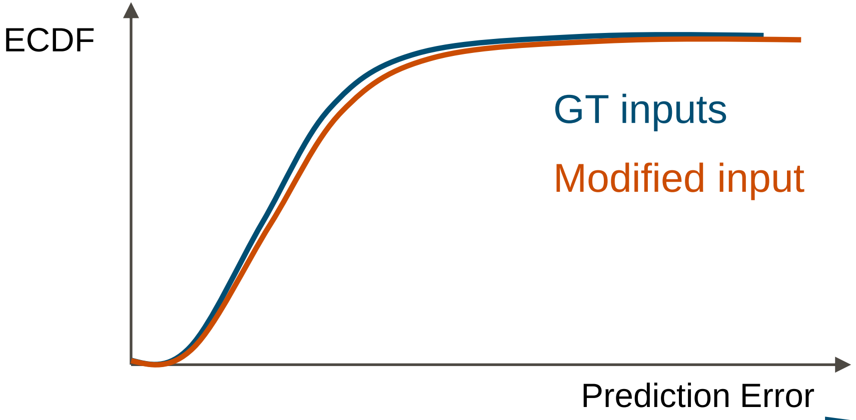


Problem

- Inherent uncertainty in prediction task
- Typical outputs discrete trajectories
- Probabilistic predictions not verifiable
- Single scenario not interpretable



Proposed solution

- Consider prediction performance
- Global evaluation across dataset
- Empirical cumulative distribution function of errors
- Compare two error distributions

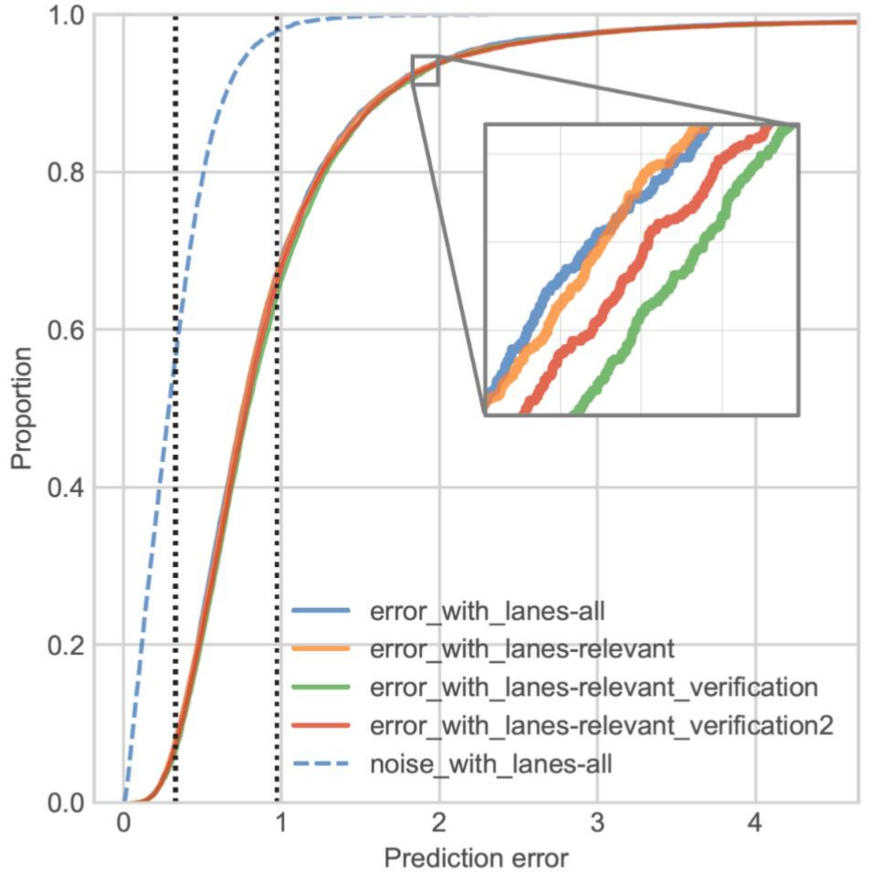
Validation: Methodology III

Problem

- What constitutes significant difference?
- All distributions visually similar

Proposed solution

- Statistical test for similarity
- Likelihood of two observations belonging to same underlying distribution
- Considers available data
- Multiple runs for non-determinism
- Plot boxplots of p-values



Validation: Verification and Results

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Validation

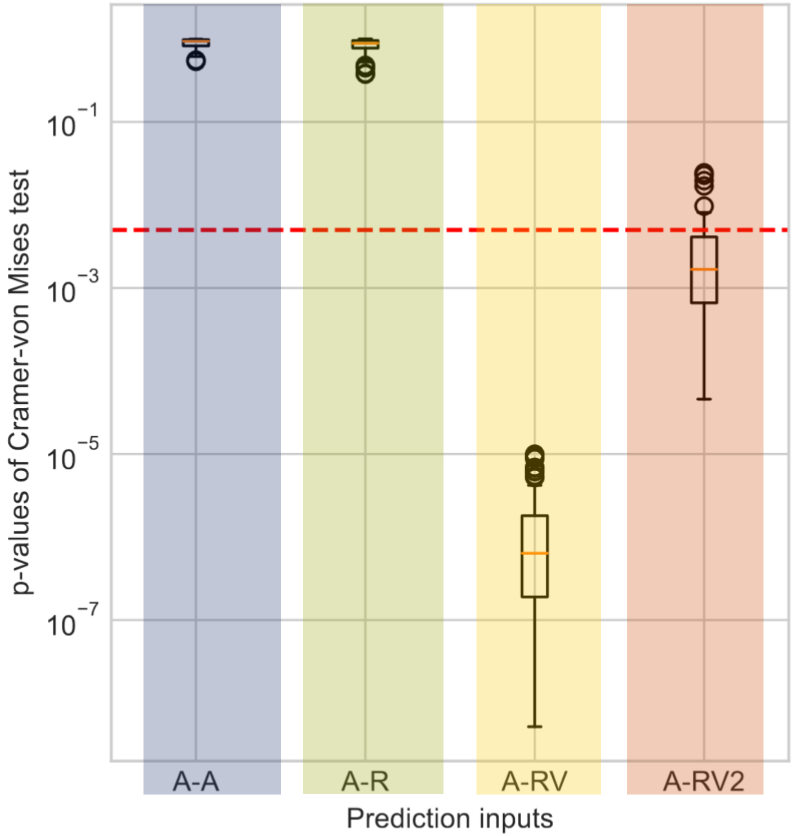
- Verify with implausible criteria
- All-All (A-A) as baseline for fluctuation

Results

- Same GT inputs show fluctuation
- Remove all objects
- Remove 5% objects in front of vehicle
- Remove 10% irrelevant objects

→ Validation identifies invalid inputs

→ Validation supports results



Discussion & Conclusion

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Validation Procedure

- Novel method based on motion prediction DNN
- Reconciles analytic criteria with context aware DNN
- Verified sufficient sensitivity

Relevance

- Derived interpretable model for relevance confirmed by validation

Limitations

- Validation dataset does not contain near-accidents
- Sensitivity of validation procedure unknown

Outlook

- Simulator studies and critical scenarios