OPEN QUESTIONS IN TESTING OF LEARNED COMPUTER VISION FUNCTIONS FOR AUTOMATED DRIVING,

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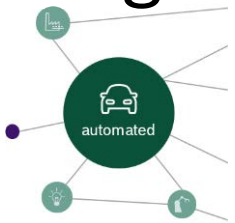
Automated Driving



- Level 4/5 automated driving in an urban environment
  - High demands on safety and performance in highly complex scenarios
- Classical software verification methods and coverage criteria not sufficient
  - Tests and coverage need to be defined on the domain, not only on the software structure as today
  - Particularly, if autonomy is supported or (partially) implemented by machine learning

Goal: Make Testing Economically Feasible

∞ *reduce to* → **N**

Coverage of input domain of autonomous system theoretically requires infinitely many test cases due to open context -> **finite test set**

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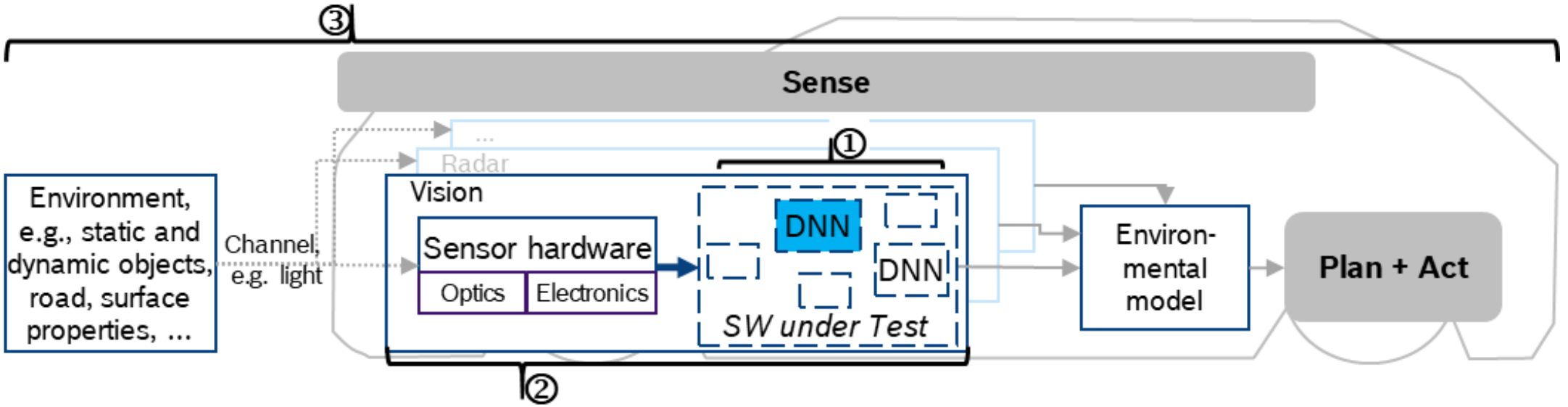
System context: Vision function in an automotive context



How do we create good (relevant and meaningful) test data efficiently for a CV function interpreting images of driving scenes in the physical world? How do we verify relevant properties of the corresponding DNNs?

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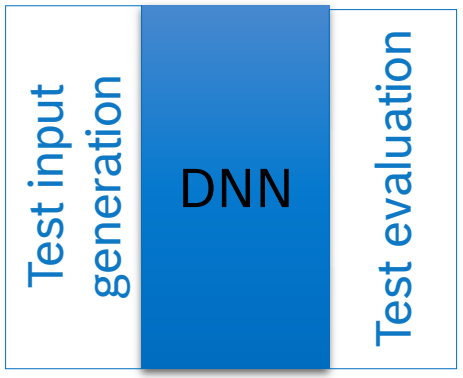
Summary of the paper



- Synthesis of work from autonomous driving, software testing, computer vision and machine learning
- Overview of
  1) test generation
  2) test evaluation methods
- 11 Exemplary research questions

Different view point to literature for training & validation in machine learning:

- *In training we focus on comparing average case behavior based on cost metrics - mainly to evaluating competing designs*
- *In verification and testing we are typically concerned with (worst-case) behavior w.r.t. specific properties.*

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Test generation: Leveraging synthetic data

https://github.com/carla-simulator/carla

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(+) Generate dedicated samples to cover the domain
(+) Labels and meta-data inherently available
(-) Required affordances and fidelity [1]
(-) Residual risk w.r.t simulation and its fidelity [2]

Synthetic \ Real	Desirable	Violation
Test passes	Accepted desirable	Missed violation
Test fails	False alarm	Caught violation

Exemplary Research Question: Which affordances should a simulation provide to support building a good test set with domain coverage?

[1] Hutter, A.: Einsatz von Simulationsmodellen beim Test elektronischer Steuergeräte. In: Sax, E. (ed.) Automatisiertes Testen Eingebetteter Systeme in der Automobilindustrie. Hanser (2008)
[2] Koopman, P.,Wagner, M.: Toward a framework for highly automated vehicle safety validation. Tech. rep., SAE Technical Paper (2018)

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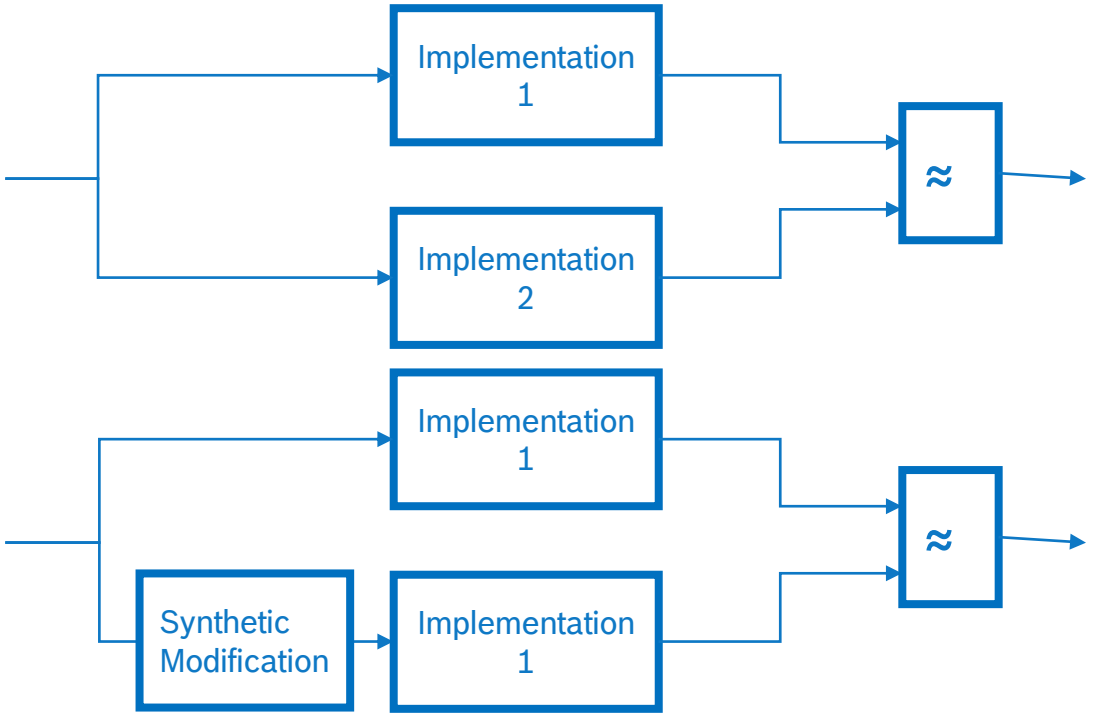
Test evaluation: Invariance



Differential testing

- Requires two implementations
- Only shows inconsistencies
- Example: DeepXplore [3]

Metamorphic testing

- Requires synthetic data modification
- Relies on synthetic data evaluation (above)
- Example: DeepRoad [4]

Exemplary Research Question: How can we use specifications and formal methods to reap a larger benefit from ground truth data to effectively multiply our test set?

[3] Pei K, Cao Y, Yang J, Jana S. DeepXplore: Automated whitebox testing of deep learning systems. Proc. SOSP 2017,1–18.
[4] Zhang M et al.. DeepRoad: GAN-based metamorphic testing and input validation framework for autonomous driving systems. ASE 2018,132–142.

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THANK YOU

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Proposed research questions for test input generation

- Sampling around Labeled Test Images:
  - What notions of robustness and corresponding test images should be included in a good test set?
  - Which kind of coverage criterion could be used to argue exhaustiveness of a test set?
  - What data augmentations should be used on images in a good test set?
- Domain and Data Analysis:
  - What would be a basic check list of nuisance factors and other hazards that should be considered for a good test set?
  - How do we integrate knowledge from the analysis of the ODD and OEDR into designing a good test set?
  - How to concertize abstract tests into concrete images?
- Synthetic Data
  - Which affordances should a simulation provide to support building a good test set with domain coverage?
  - How can we leverage synthetic data to economically scale a good test set?

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Proposed research questions for test evaluation

- How do we obtain ground truth for diverse test data in a cost-effective manner?
- What are relevant, task-and domain-specific evaluation metrics?
- How can we use specifications and formal methods to reap a larger benefit from ground truth data to effectively multiply our test set?

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