Advanced Testing of Deep Learning Models: Towards Robust AI

Winter Semester – 2024-25

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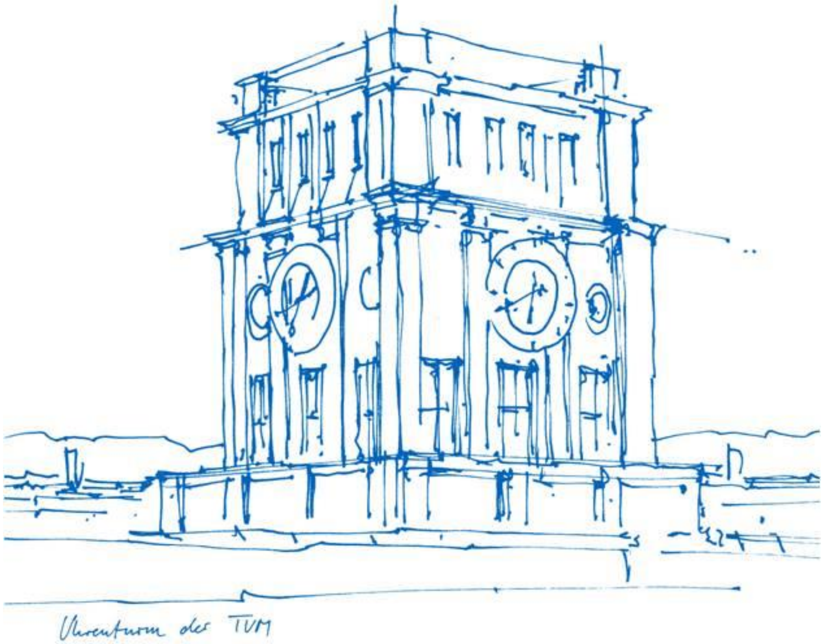
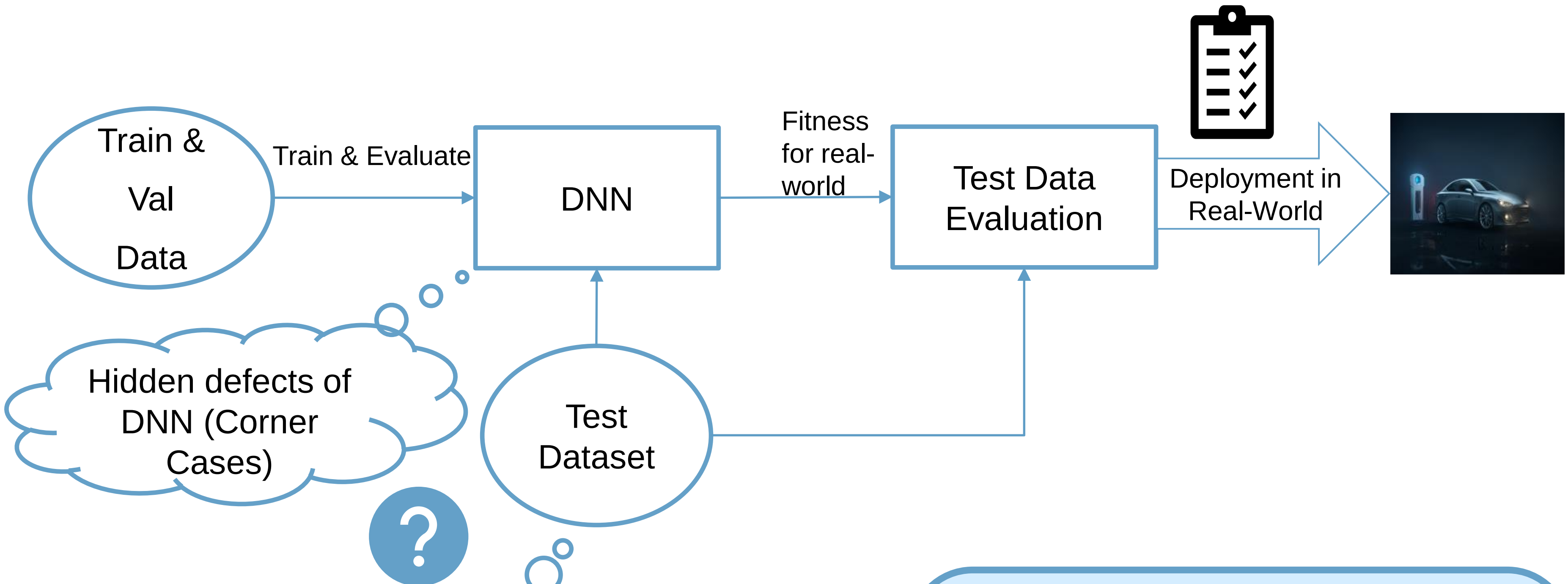


The world of AI testing



1. Hand Picked Test set
2. Inadequate test dataset
3. Statistical measure about the quality of test dataset?

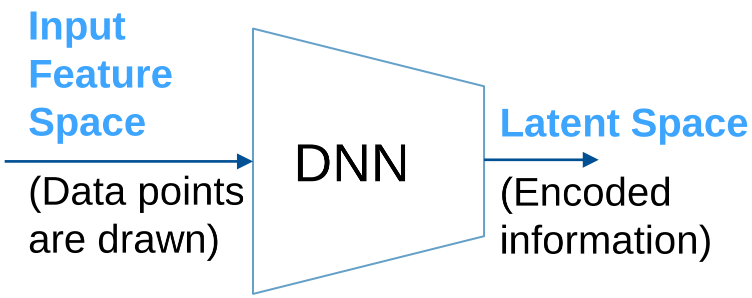
- **<u>DNN Testing</u>**

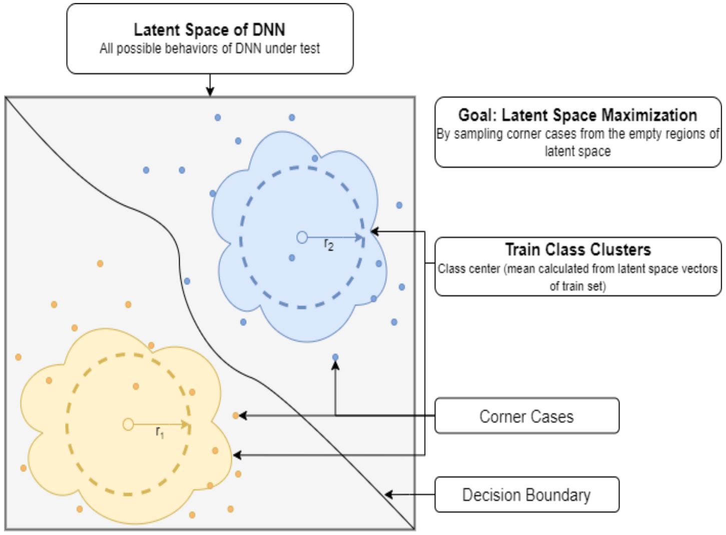
  How to identify corner cases?

- **<u>Dataset Quality Evaluation</u>**

  How to evaluate dataset quality for safety assured performance?

Exploring Latent Space Coverage

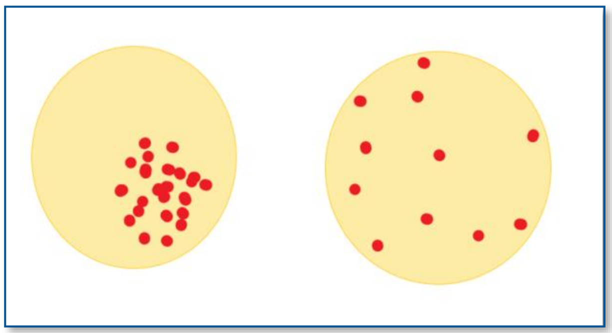




- **<u>Dataset Quality Aspects:</u>**
  - Robust test dataset: e.g. Accuracy- 0%
  - Diverse test dataset: Test more underlying faults
- **<u>Latent Space Coverage:</u>**

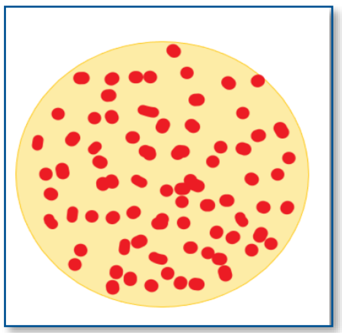
➢ Coverage, Density & Sparsity Estimation
  - Verify training policies
  - Estimate potential data collection gap

Exploring Latent Space Coverage



Dense and Sparse test data points in Latent Space

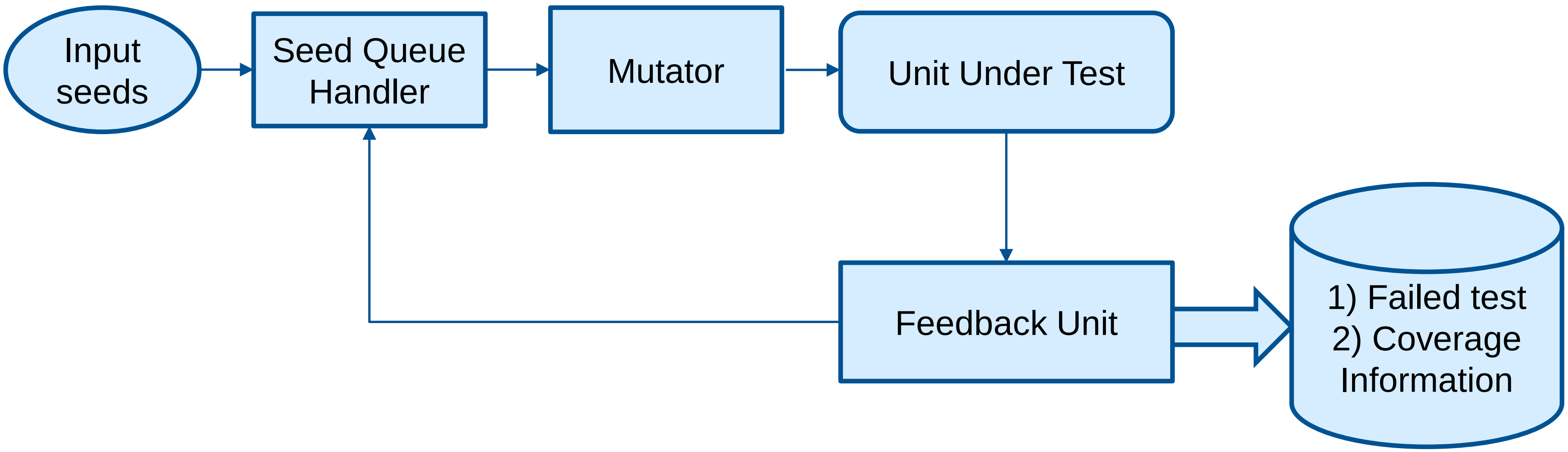
Is this a true maximization of latent space coverage?



Ideal test data points in latent space

- **<u>Directly using Latent space vectors:</u>**
  - GANs & VAEs
- **<u>Corner Case Identification:</u>**
  - Coverage-guided Fuzz Testing
  - Latent Space based Testing
  - Metamorphic Relation Testing

Coverage-Guided Fuzzing



Metamorphic Testing

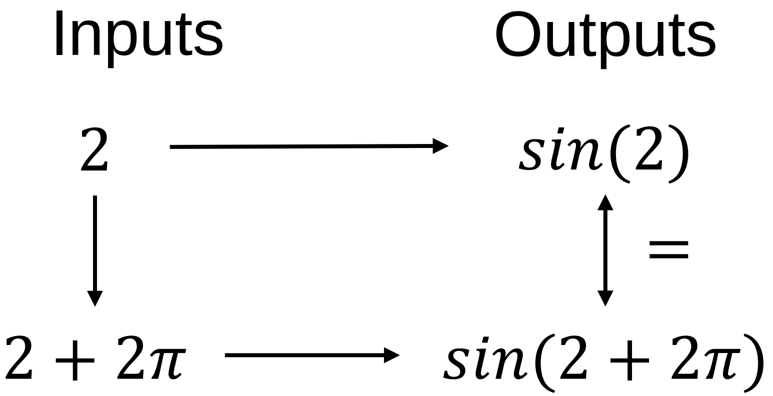
- Metamorphic Testing (MT) is one method to solve the oracle problem for Deep Learning Models
  - There are usually no oracles for DL models
  - Metamorphic testing can be seen as a pseudo-oracle/model
  - Reverse engineering of a part of the specification

- Metamorphic Relations (MR) need to be defined in order to compute test cases
  - Source test inputs are used to compute follow-up inputs
  - Both inputs (source and follow-up) are fed into the System Under Test (SUT)
  - Both outputs and both inputs are compared to check whether the MR holds true

Metamorphic Testing

- **Example:** Testing the implementation of the $\sin(x)$ function
- **Assumption:** We implement a test case $\sin(2)$ but don't know what the correct output
- **Metamorphic Testing:** Creation of a *follow-up test case* $\sin(2 + 2\pi)$ which is expected to have the same output as the *source test case* $\sin(2)$
- **Test Case Evaluation:** We check if the relation $\sin(2) = \sin(2 + 2\pi)$ holds. If yes, the test case *passed*

sin() Example:



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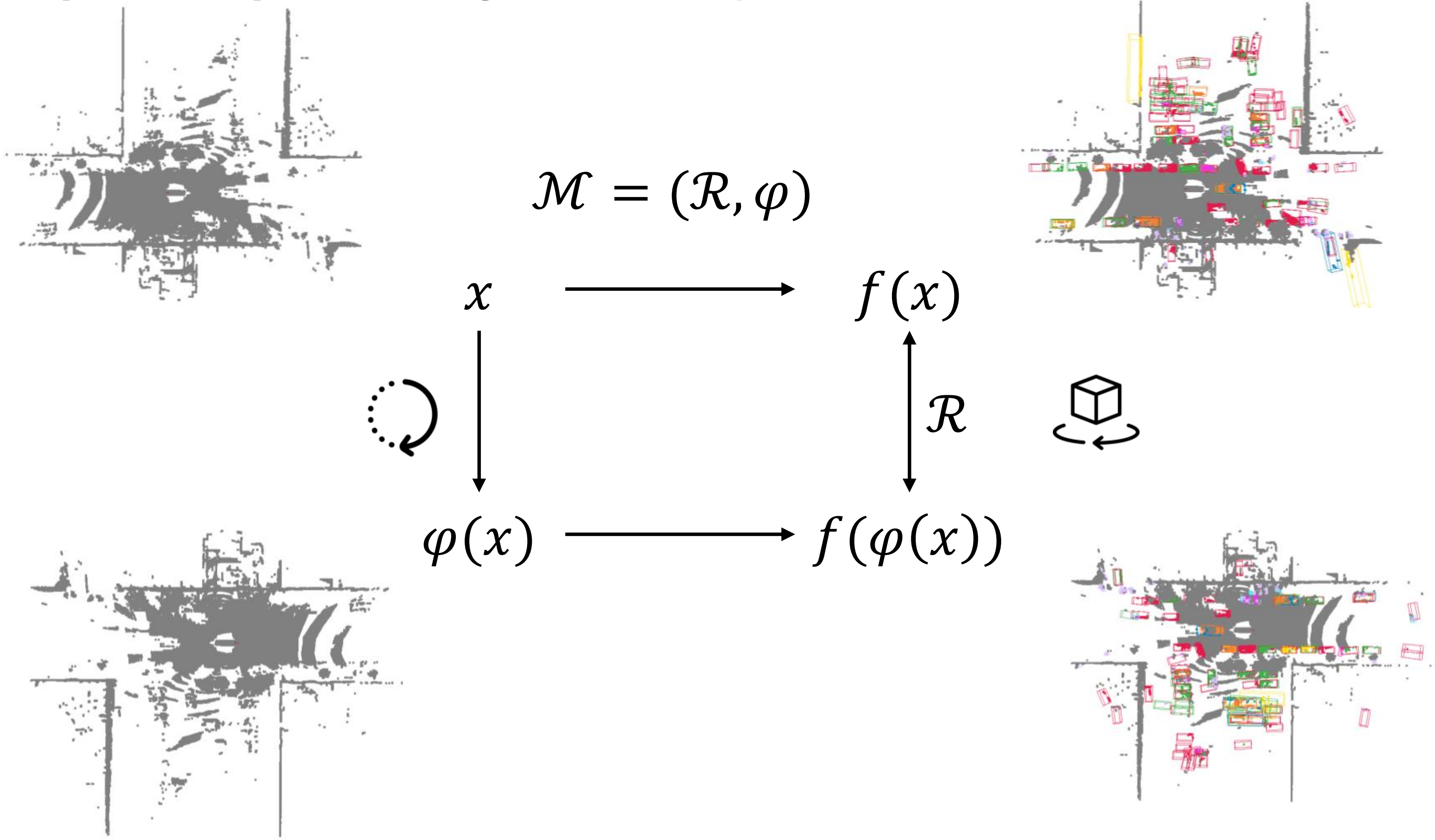
Metamorphic Testing

Example: Deep Learning LiDAR object detection model:



Metamorphic Testing

Example: Deep Learning LiDAR object detection model:

- Testing of a LiDAR object detection model:
- $\varphi(x)$: Rotation of the follow-up point cloud by 180°
- $\mathcal{R}$: Inverse 180° rotation of all output 3D bounding boxes. Then we check if all follow-up bounding boxes have a corresponding bounding box in the source output.

Learning Outcomes

- **Implementation, testing & evaluation** of state-of-the-art Classification & 2D Object Detectors DNNs
- Corner Case data generation using fuzzing, metamorphic relations and latent space properties
- GANs & VAEs for latent space coverage maximization
- Adversarial Attacks for state-of-the-art Classifiers and 2D Object Detectors

Prerequisites

Required

- Python (of course ☺)
- Deep Learning Frameworks (PyTorch, Keras, TensorFlow)
- Linux / Windows

Good to have

- Insights of 2D Object Detector Networks (SSD, Yolo, RCNN)
- Understanding of latent space and vector space modelling
- Passion for Safe AI

….But every smart work requires sincere dedication & commitment!

Agenda

- **Pre-course Meeting:** 04.07.2024
- **Apply with additional documents: till 20.07.2024**
- **Acceptance Notification:** 25.07.2024
- **Kick–off Meeting - 1:** XX.10.2024 (Di.)
- **Project Discussions & Allocation:** XX.10.2024 (Di.)
- ***Weekly Follow-ups***
- **Mid-term Presentations:** TBD (Preliminary-Do.)
- **Final Presentations:** Feb.2025 (Preliminary-Do.)

Interested?

1. Give your 1st priority to this course in the matching system
2. Tell us more about you (motivation, CV, transcripts & Gitlab link) by filling out:
   [TUM_I4_student_wiki]

Thank you for your attention ☺

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Garching bei München