Improving Ecology and Economics of High-pressure Aluminum Die Casting Processes

A data-driven analytical characterization of hidden pores and defects using low-cost X-ray radiography images and advanced simulation methodologies

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How can we detect and characterize hidden defects in materials low-cost and high-quality?

Reducing defects in materials improves robustness, ecology, and economics.

OBJECTIVES

Robust detection and characterisation of hidden defects, e.g., pores or cracks, is a still challenge.

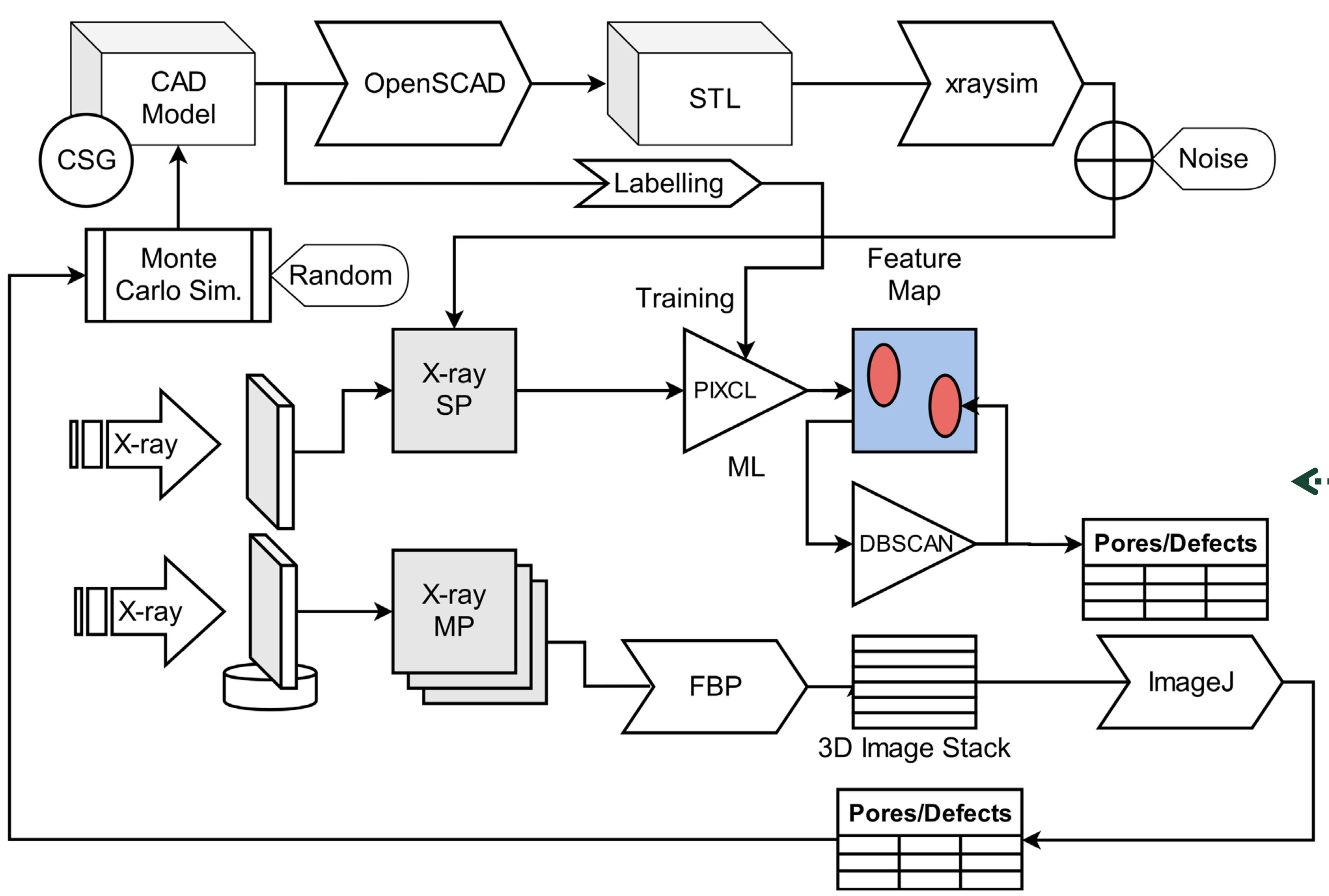
Knowledge about defects enables improvement of design, production, and life-time.

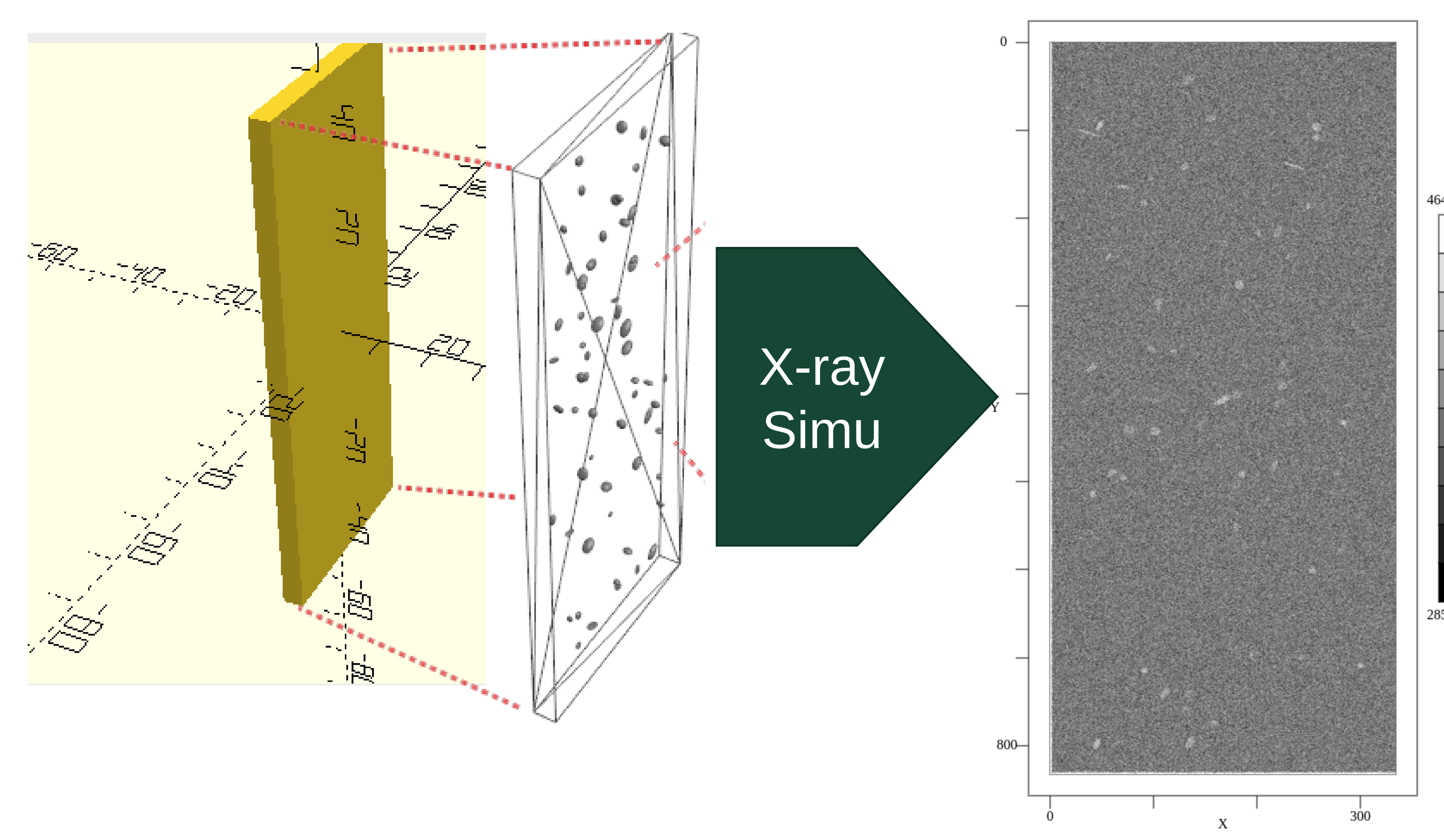
- Common Measuring Techniques: X-ray Radiography/CT, US Sonography
- Visual inspection and characterization is error prone and time-consuming
- Automated damage and defect diagnosis is required
- But data-driven models require **ground truth data** set and advanced work flow

Missing!

Creating!

Using…





METHODS

- **X-ray Radiography** (LowQ, MidQ)
- X-ray Computer Tomography Reconstruction (Reference, HighQ)
- **X-ray Image Simulation**
- CAD Modeling of defects using **Monte Carlo Simulation**
- **Semantic CNN Pixel Classifier and DBSCAN** for Feature Marking

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The Reality Gap: Noise, Bias, and Artifacts

Good and Bad News

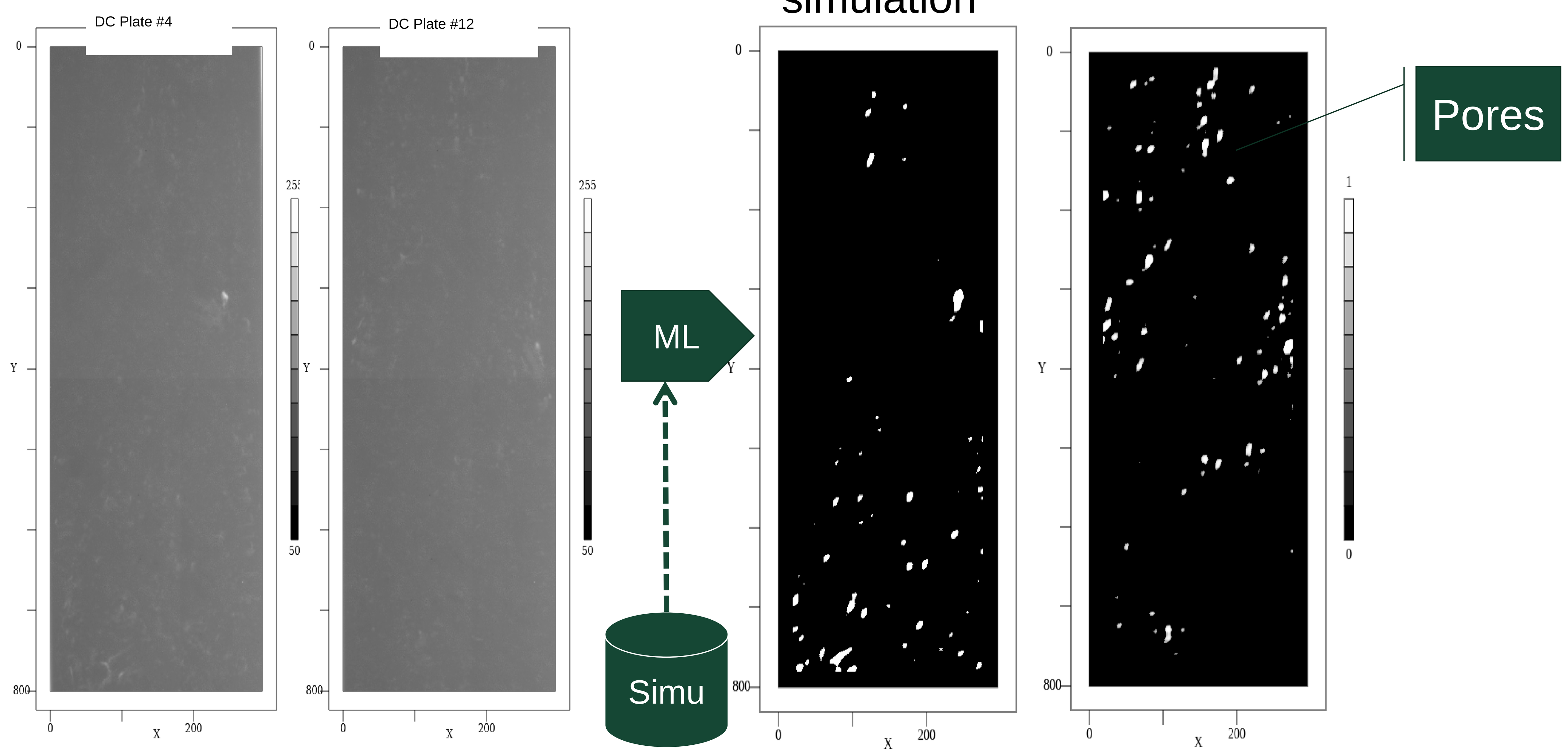
Do not trust data-driven models!

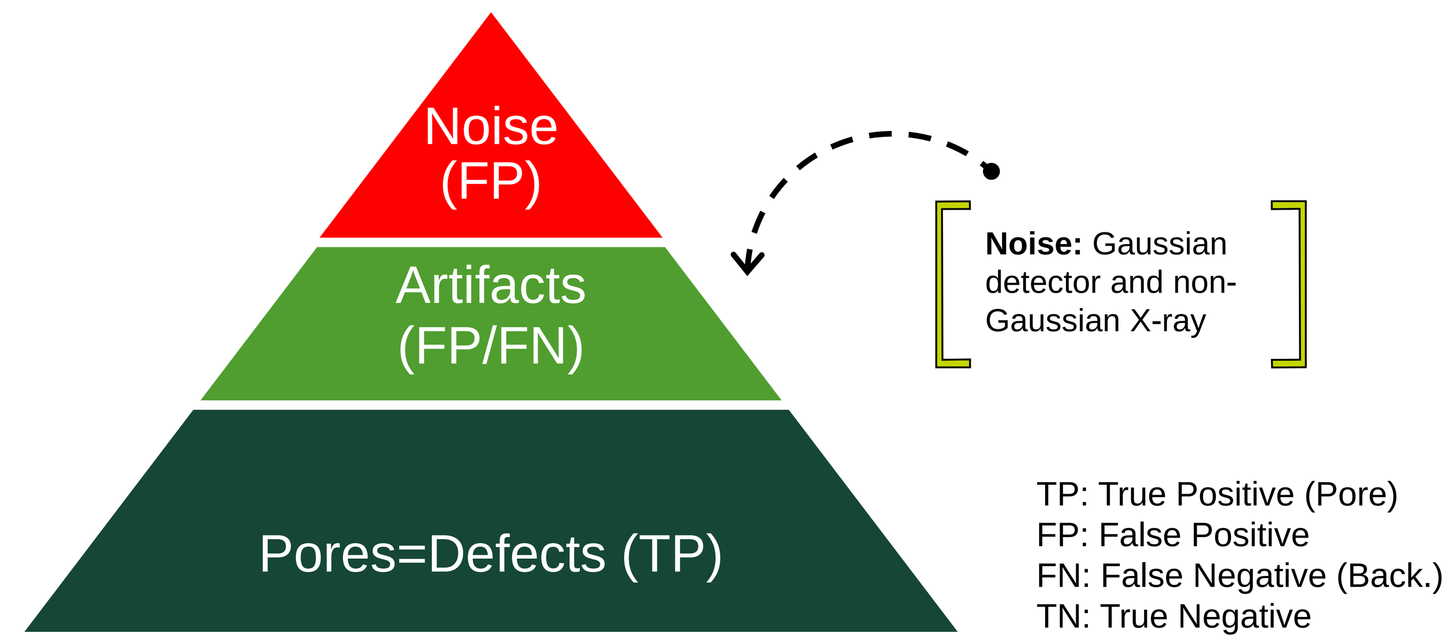
RESULTS

A simple data-driven feature marking detector is suitable to detect pores in low-contrast and low-cost X-ray radiography images.

Simulation of X-ray image data sets for the training of the detector is valid and suitable.

- ✓ A data-driven image feature detector trained using synthetic data only can be applied to real measured images
- ❑ But noise, simulation bias, and computational artifacts decrease the feature marking accuracy (too much FP)
- ✓ Missing Ground truth problem solved by simulation





CONCLUSION

- **Semantic pixel classifier is robust against Gaussian detector noise, but highly sensitive to non-Gaussian spatially correlated X-ray noise**
- **Due to the missing ground truth in real world images, the feature marking model must be trained with synthetic images derived from CAD models**
- **Artifacts (FP) were observed in feature maps of synthetic X-ray images independent of the CAD model and of defect-free materials!**

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