

Praxis der Forschung: *Probabilistic Object Detection with Conformal Prediction*

Object detectors in real-world scenarios face challenges such as weather variations, occlusions, and sensor noise. To ensure their reliability when deployed, object detectors must not only detect objects but also estimate the uncertainty in their predictions. This project explores common uncertainty quantification methods and investigates conformal prediction as a complementary framework to provide statistically reliable confidence intervals. Overall, the project aims to enhance robustness and reliability in safety-critical applications including autonomous driving and medical imaging.

Research Focus for Students:

1. Understanding Probabilistic Object Detection:

- Students will explore different probabilistic object detection frameworks.
- They will study how uncertainty-aware models compare to traditional deterministic approaches.

2. Uncertainty Estimation Methods:

- Students will investigate methods to quantify uncertainties, including Bayesian approaches and deterministic techniques such as Deterministic Uncertainty Quantification (DUQ), Ensembles, and Evidential Deep Learning.
- They will compare these methods regarding calibration properties in object detection tasks via metrics such as Expected Calibration Error (ECE) and Negative Log-Likelihood (NLL). Additionally, students will evaluate the impact of each method on overall detector performance using standard object detection metrics, including Mean Average Precision (mAP).

3. Separation of Different Uncertainties:

- Students will understand the concepts of aleatoric uncertainty (data-dependent) and epistemic uncertainty (model-dependent) and relate these to the uncertainty estimation methods from 2.
- They will implement and compare techniques that separate these uncertainties in object detection models.
- The effectiveness of these approaches across different domains (e.g., autonomous driving, medical imaging) will be evaluated.

4. Conformal Prediction for Object Detection:

- The project will explore conformal prediction as a framework for generating statistically valid confidence intervals for object detection outputs.
 - Students will implement conformal prediction methods to refine the reliability of uncertainty-aware object detection models, ensuring that predictions meet desired coverage guarantees.
5. Integration into Real-World Object Detection Pipelines:
- Students will evaluate probabilistic object detection models on benchmark datasets.
 - They will integrate conformal prediction techniques into state-of-the-art detection architectures.
 - The project will explore how to optimize these methods for efficiency in real-world applications.

Contact:

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References:

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