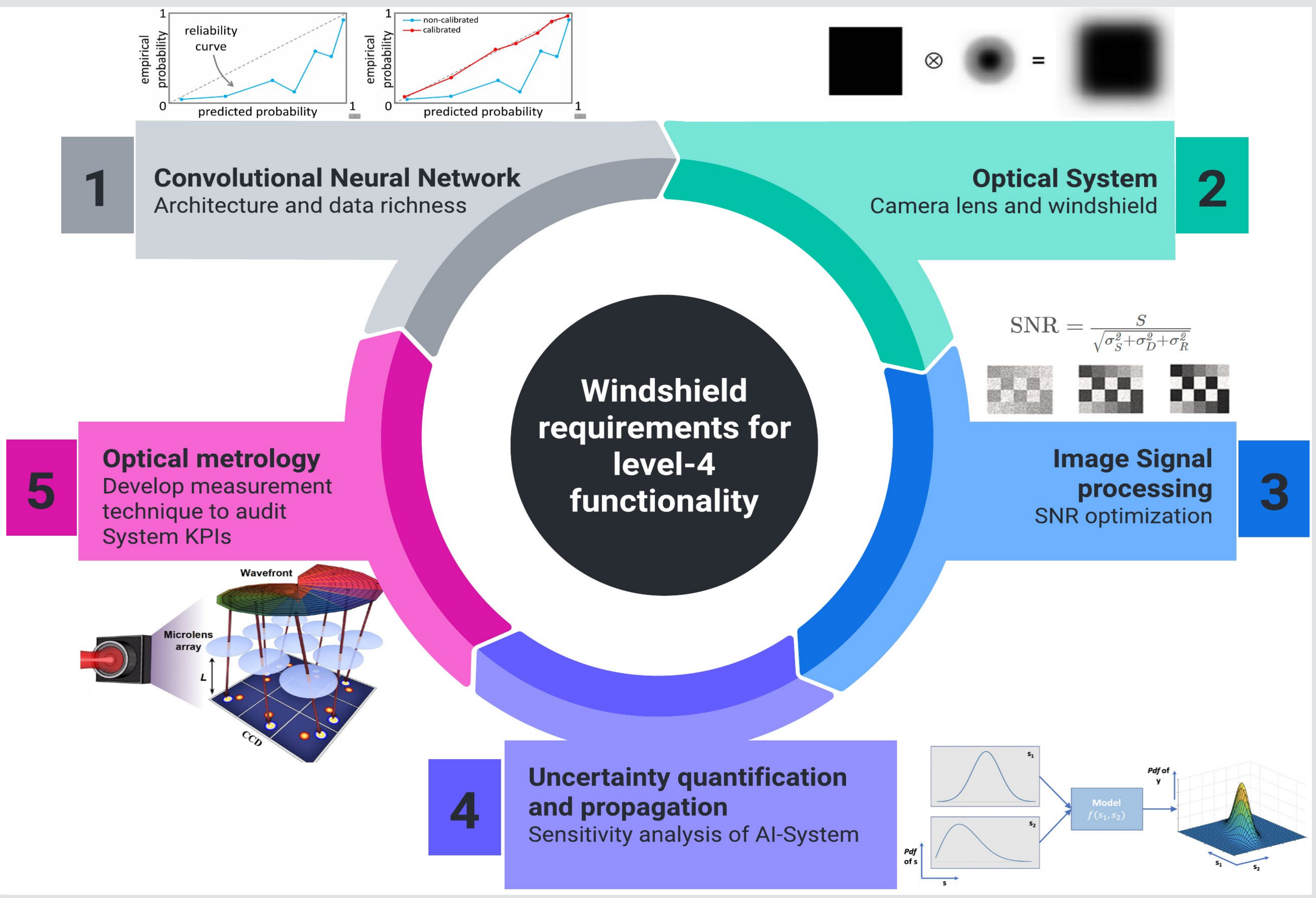
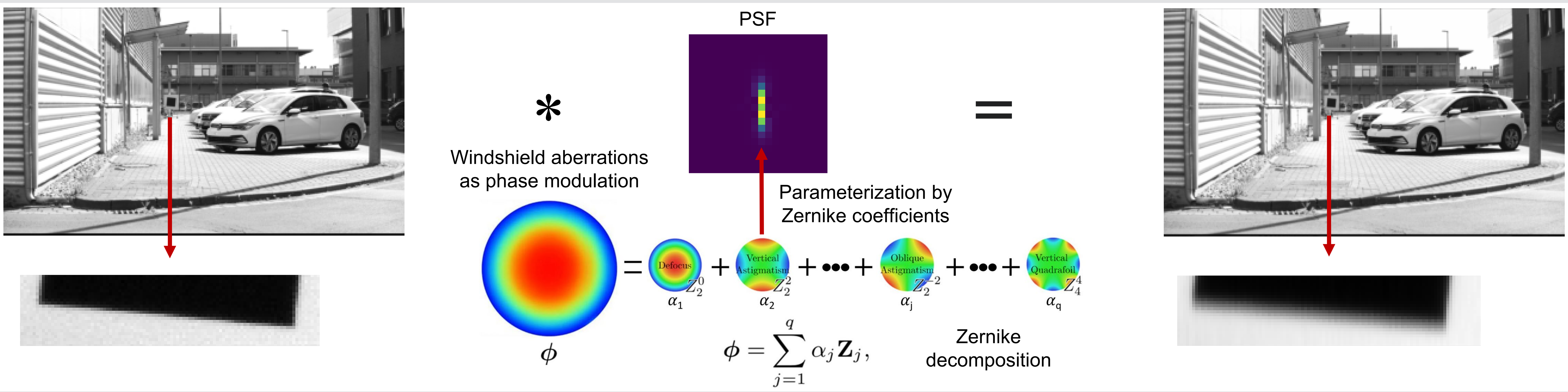
Sensitivity analysis of AI-based algorithms for autonomous driving on optical wavefront aberrations induced by the windshield

Dominik W. Wolf (M.Sc.)
Doctoral candidate
EGEM/O

Problem Scope

- Autonomous driving heavily relies on Computer Vision
- Autobahn use case requires long-focus cameras
- Long-focus cameras are very sensitive for optical aberrations
- Aberrations blur the image by the PSF of the optical system
- Optical aberrations induced by the windshield generate dataset shifts
- Dataset shifts deteriorate the performance of AI-algorithms
- Safeguarding autonomous driving functionalities puts optical requirements on the windshield
- Bijectivity between optical system metric and AI merit function required
- Optical KPI needs to be measurable for quality assurance purposes
- How does this metric correlate to current governing quality standards?

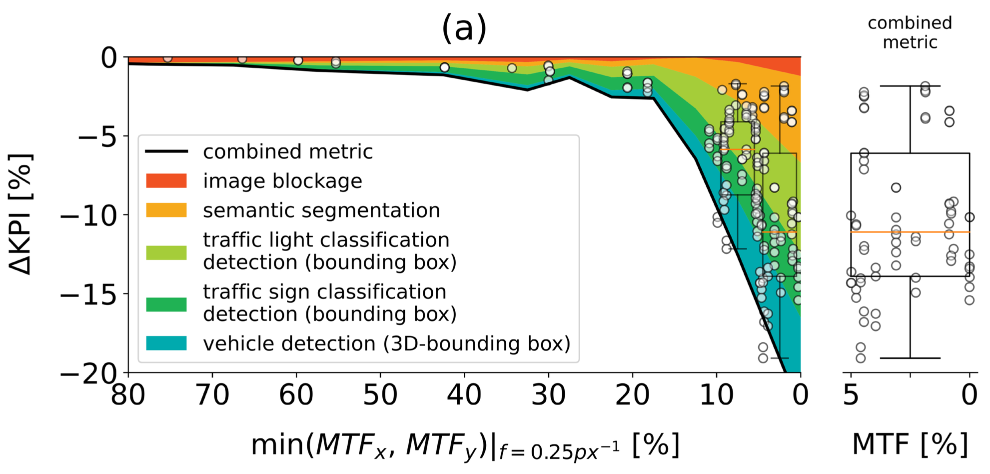




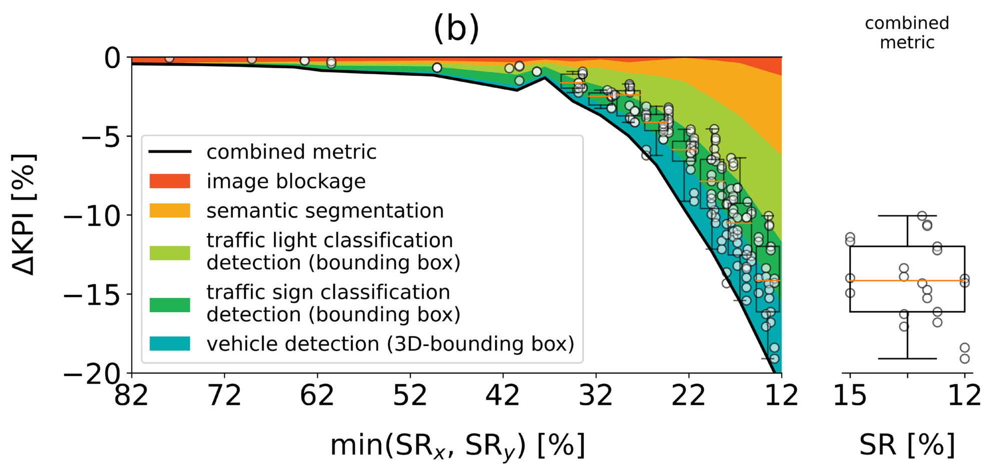
Results to: 1 2

AI-algorithms vs. optical system performance

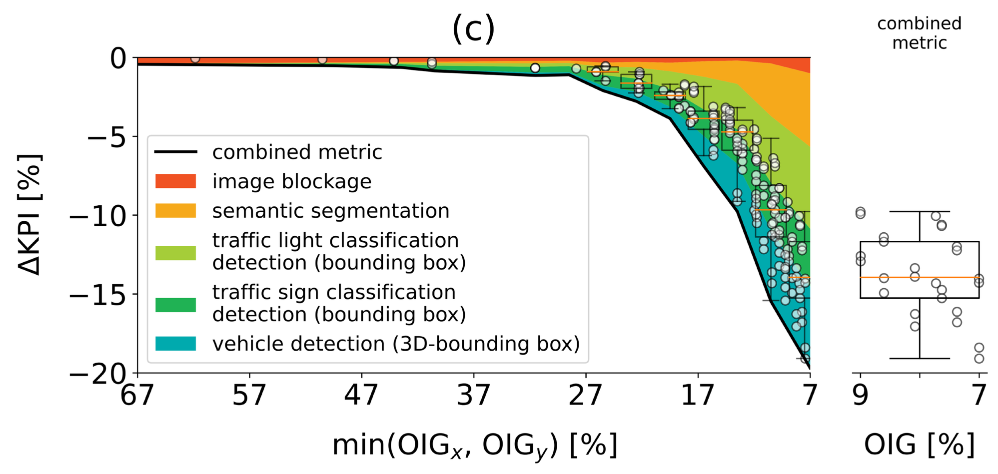
- MTF at half Nyquist correlates poorly to the AI-KPIs:



- Strehl ratio establishes a weak correlation to the AI-KPIs:



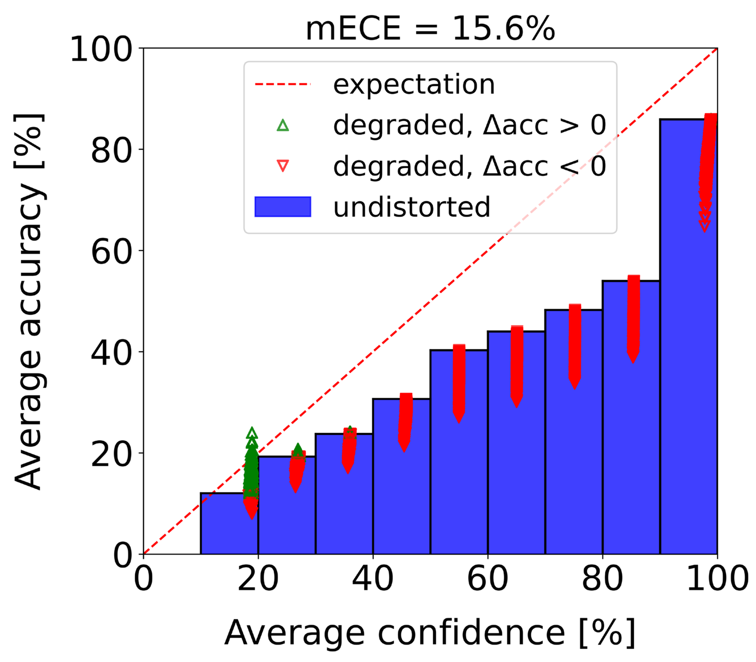
- Optical informative gain shows slightly stronger correlation:



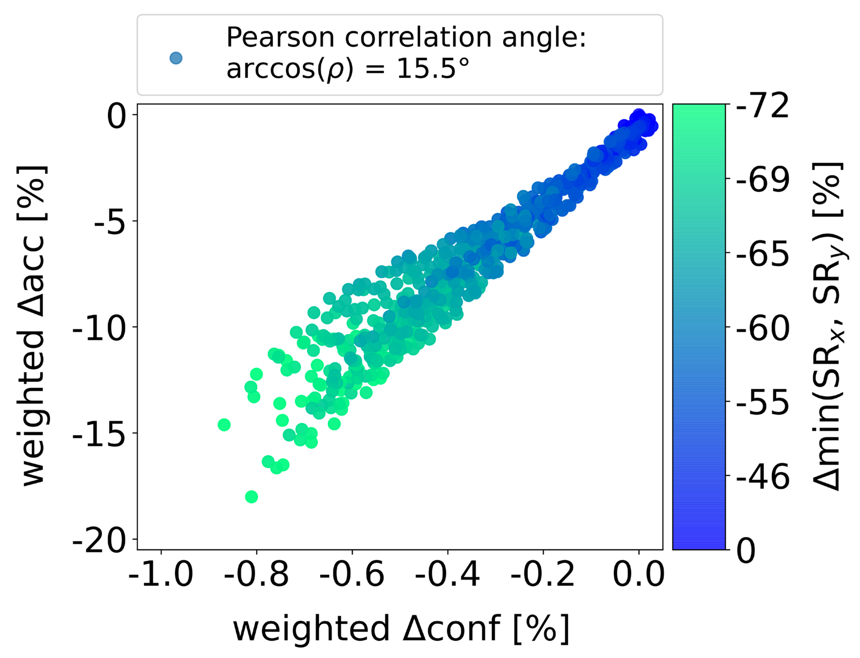
Results to: 1 4

Prediction uncertainty vs. optical system performance

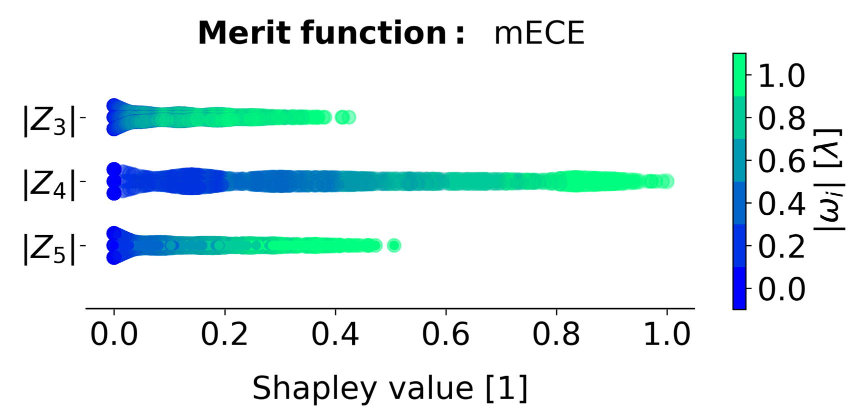
- Model overconfidence increases:



- Δaccuracy >> Δconfidence:



- The sensitivity of the mECE on independent optical aberrations has been quantified in terms of Shapley values, where the Zernike coefficients serve as features of the optical model:



Results to: 5

- Refractive power – as the wavefront aberration curvature along a specified direction – is fundamentally incapable of capturing information about the PSF and the oblique astigmatism (Z_3) in particular.
- The System MTF is not multiplicative due to the LTI-constraint violation.