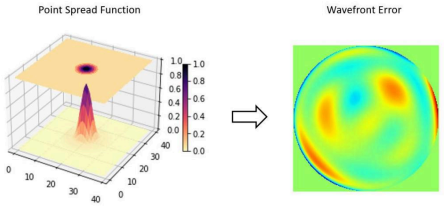
Phase Retrieval from Point Spread Function with Deep Learning Compared to Machine Learning

Wanting Xie
Stanford University, KLA Corporation

Motivation

- Phase or Wavefront Error (WFE) of an optical system can be retrieved from Point Spread Function (PSF).



Related Work

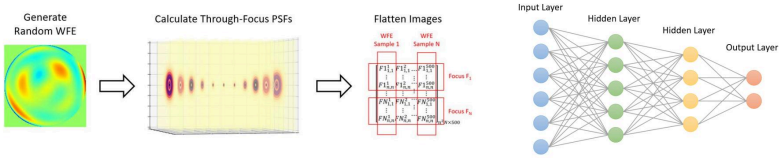
- Traditional algorithms like Gerchberg-Saxton and Fienup require multiple intensity measurements at different object-plane positions or various angles, and they are often iterative, requiring high computational power. [1]
- Machine Learning and Deep Learning have been explored for phase retrieval. [2-4]

References

[1] Gerchberg et al, A practical algorithm for the determination of phase from image and diffraction plane pictures, Optik (Stuttg.), 1972
[2] Ju et al, Feature-based phase retrieval wavefront sensing approach using machine learning, Optics Express, 2018
[3] Dzyuba et al, Optical phase retrieval with the image of intensity in the focal plane based on the convolutional neural networks, Journal of Physics: Conference Series, 2019
[4] Chimitt et al, Phase retrieval of a point spread function, Unconventional Imaging, Sensing, and Adaptive Optics, 2024

New Technique

- Generate Through-Focus PSFs from Random WFE Samples
- Model Training: Machine Learning (LR) vs. Deep Learning (FCNN)



Experimental Results

- Trained model was employed to test 100 samples.
- The retrieved WFEs were compared with the ground truth to evaluate the model's accuracy and performance.
- Machine Learning vs. Deep Learning
  - Accuracy (mWaves): 4.4±4.1 vs. 11.6±4.6
  - Training Time (sec): 6 vs. 781

$$RSS\ Error = \sqrt{\sum_{n=1}^{n} |c_{i_{predict}} - c_{i_{truth}}|^2}$$