
A Study of Network-based Wavefront Estimation with Noise

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Abstract

We provide an extended COMPASS simulation study of our existing Machine Learning based approaches to wavefront estimation using Convolutional Neural Networks (CNN). These proceed by training a UNet to estimate the wavefront phase from a wavefront sensor image. That network has application in PSF-R workflows and AO control; both considered here. We make several extensions and novel contributions. First, evaluating historical networks we study the spacial frequency response of network-based wavefront reconstruction for networks trained under distinct loss regimes; with and without an adversarial loss. Second, we study network-based estimation with low magnitude guide stars, a setting where photon noise and read-out noise can impact performance. We train new networks that use Deformable Mirror (DM) shape along with WFS data as input, as we find including the DM shape to be broadly advantageous. We evaluate the impact of a low signal to noise ratio under a learning regime that employs an adversarial loss. Previous work found that learning regime to be best when producing networks for PSF-R. We find that noise substantially impacts training performance in this setting, and also the utility of such networks for PSF-R. On the other hand, training networks without adversarial loss yields robust and performant networks in the presence of noise. We evaluate such networks in a detailed control case study.

Keywords: Machine Learning, Wavefront Estimation, Noise, Control, PSF, R, Modal Analysis, cGAN, UNet

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