

Training and Optimizing the Deep Optics Preconditioner for the Pyramid Wavefront Sensor

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The Pyramid Wavefront Sensor (PWFS) [1] is one of the preferred choices to measuring wavefront aberrations for adaptive optics in highly sensitive astronomical applications. Despite its high sensitivity, the PWFS offers a limited linear range of operation that can only be extended through the modulation of the pyramid, which involves additional mechanical and movable parts, complicating the optical setup and its calibration and operation. Nevertheless, modulation decreases the sensitivity in exchange of the extended linearity range. Inspired by artificial intelligence techniques, we designed [2] a passive diffractive layer that acts as an optical preconditioner to the PWFS, with the aim of extending the linearity range without the need for modulation. The design of the novel Deep Optics PWFS (DPWFS) is obtained through an End-2-End optimization scheme that involves, firstly, the physical modeling of the optical propagation path of the modified PWFS up to the measured intensity patterns at the detector level, and secondly, the mathematical estimation using a linear model. Then, the estimation error is used to feed the backpropagation through the models to update the diffractive layer. Considering as initial point the PWFS without modulation, the training process is performed using a variety of wavefront maps from realistic turbulence models at different strengths, most likely situated in the zone where we want to force the response of the sensor to become more linear. As shown in Fig.1, simulation results suggest that the DPWFS excel for estimating turbulence without requiring modulation, being competitive to the PWFS with modulation. On the other hand, the DPWFS is not benefited from modulation as the original PWFS. In this work, we will show our efforts to understand the importance and impact in terms of linearity and sensitivity of selecting the training parameters such as the dataset statistics, turbulence range, adding or not detector or photon noise, enabling beam modulation, calibration set point, and incorporating experimental constraints.

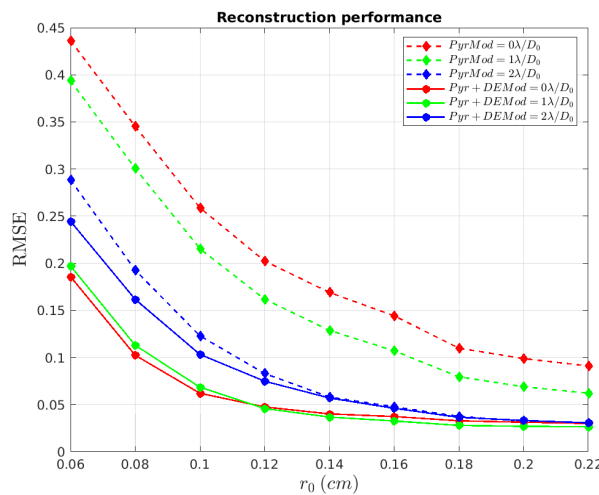


Fig. 1 Simulation results. Comparison of the estimation error for the PWFS and the DPWFS for various modulation options for a 3m telescope.

References:

- [1] Ragazzoni, R., "Pupil plane wavefront sensing with an oscillating prism," *Journal of modern optics* 43(2), 289-293, 1996.
- [2] Guzman, F., et.al., "Deep Optics Preconditioning for Enhanced Pyramid Wavefront Sensing," to be submitted 2023.