Co-phasing segmented-telescopes via deep-learning techniques

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Abstract

The concept of segmented telescope is unavoidable to build extremely large telescopes (ELT) in the quest for spatial resolution, but it also allows one to fit a large telescope within a reduced volume of space (JWST) or into an even smaller volume (Standard Cubesat). Cubesats have tight constraints on the computational burden available and the small payload volume allowed. At the same time they undergo thermal gradients leading to large and evolving optical aberrations.
The pupil segmentation comes nevertheless with an obvious difficulty: to co-phase the different segments. The CubeSat constraints prevent the use of a dedicated wavefront sensor (WFS) making the focal-plane images acquired by the science detector the most practical alternative. Yet, one of the challenges for the wavefront sensing is the non-linearity between the image intensity and the phase aberrations. Plus, for Earth observation, the object is unknown and unrepeatable. Recently, several studies have suggested Neural Networks (NN) for wavefront sensing; especially convolutional NN which are well known for being non-linear and image-friendly problem solvers.

We study in this paper the prospect of using NN to measure the phasing aberrations of a segmented pupil from the focal-plane image directly without a dedicated wavefront sensing.

In our application we take the case of a deployable telescope fitting in a CubeSat for Earth observations which triples the aperture size (compared to the 10cm CubeSat standard) and therefore triples the angular resolution capacity. In order to reach the diffraction-limited regime in visible wavelength, typically a wavefront error below lambda/50 is required. The telescope focal-plane detector, used for imaging, will be used as a wavefront-sensor. In this work we study a point source, i.e. the Point Spread Function (PSF) of the optical system as an input of a VGG-net neural network, an architecture designed for image regression/classification.
This approach shows some promising results (about 2nm RMS which is sub lambda/50 of residual WFE with 40-100nm RMS of input WFE) using a relatively fast computational time less than 30 ms which translates a small computation burder. These results allow one further study for higher aberrations and noise.

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