Deep learning for phasing the ELT petal mode

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Abstract

Earth observation as well as astronomy are scientific domains where high angular resolution images are required to guarantee the scientific return. High angular resolution requires large telescope apertures, often necessitating segmented pupils as demonstrated by large ground-based telescopes (Keck,10-meter / 36 segments and ELT, 37-meter / 798 segments) and also for space observatories (JWST, 6-meter / 18 segments). A segmented pupil allows the telescope to deliver a bigger aperture but nonetheless comes with a significant challenge: each segment require a perfect alignment (at a fraction of the imaging wavelength, typically 50nm at visible wavelength) with respect to the others in order to reach the full angular resolution promised by the large aperture.
To reach its theoretical resolution, (4mas in visible wavelength, 12 mas in K-band) the ELT will have to be equipped with powerful AO systems, able to correct wavefront aberrations up to few tens of nanometers. Due to the 6 large spiders, (50cm width) and to the segmented surface of one of the mirrors (M4), the ELT pupil will behave as a segmented pupil, potentially degrading strongly the performance. Measuring and correcting this phasing error is crucial. This phasing can potentially be solved by using a single focal plane image by using well-known algorithms such as asymmetric pupil phase diversity for instance. However some constraints will make this type of solution limited. First the AO residuals are slowly evolving and will not be averaged out enough in the image, challenging the phasing sensor to disentangle them from phasing speckles. Second, ELT will also produce non-Kolmogorov phase residuals (Low Wind Effect) difficult to modelize, and that can be misinterpreted with phasing errors. We therefore want to explore non-linear learning methods to address this task, at least with minimal contributors at first. In this work we propose a deep learning method using a single focal plane image,using a method the authors developed for a space-borne deployable telescope.

Deep learning algorithms are well suited to this type of problem. They are well-known and widely used nonlinear problem solvers allowing a direct image parameter identification. This method is studied for a simple ELT imager without atmosphere, then with residual

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turbulence averaged over short and long periods, for different seeings and correction regimes. We study the impact of these residuals during the learning phase and on the final performance, and we look for neural network architectures that best fit the need. This method shows a phase identification allowing the telescope to reach the diffraction limit in K band. We quantify robustness when guiding on different star magnitudes and with varying amounts of high order residuals.

Keywords: Deep learning, Petal mode, Wavefront sensing