Fourier-type wavefront sensing – a general and nonlinear approach

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Abstract

Advanced Adaptive Optics (AO) instruments have applications in the future generation of Extremely Large Telescopes (ELTs). Many of these AO systems include Pyramid Wavefront Sensors (PWFSs) in their design. The classical PWFS is 4-sided and its competitors include the 3-sided PWFS and the iQuad. All of these Wavefront Sensors (WFSs) are considered Fourier-type because they use optical Fourier filtering with a suitable optical element in the focal plane. Conventionally, these sensors perform wavefront reconstruction using Matrix-Vector-Multiplication (MVM) approaches that need to be calibrated to the system. There also exist several model-based reconstructors which depend on the underlying mathematical model of the WFS. Additionally, methods like MVMs are linear techniques applied to the inversion of nonlinear Fourier-type WFS models. However, in nonlinear regimes, linear approaches critically degrade image quality due to approximation errors, sometimes compensated by the so-called optical gain.
Here we present a novel type of nonlinear reconstructor that is a generalised wavefront reconstruction method for all Fourier-type sensors. A significant advantage to this approach is its direct applicability to any Fourier-type WFS without calibration. Moreover, the algorithm has been designed to be robust in nonlinear regimes.
Several Fourier-type wavefront sensors will be considered for ELT-scale instruments and their performance evaluated for different atmospheric settings. We will investigate whether optical gain compensation is automatically included in the nonlinear wavefront reconstruction method. Comparisons will be made to linear reconstruction approaches (e.g., MVMs) operating in nonlinear regimes.

Keywords: wavefront sensing, pyramid wavefront sensor, Fouriertype wavefront sensors, optical gain, inverse problem

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