Comparison of atmospheric tomography basis functions for PSF reproduction.

Daniel Hopkins*†[1], Stephen Weddell[1], Richard Clare[1], and Le Yang[1]

[1]University of Canterbury – Christchurch, New Zealand

Abstract

Atmospheric tomography is a process used to increase the useful sky-coverage of an adaptive optics system. The atmospheric distortion of multiple point sources are estimated using measurements from wavefront sensors. Atmospheric tomography then uses the multiple point spread functions of these guide beacons to estimate and reproduce the spatially variant point spread function for a science target that is outside the isoplanatic patch of any individual guide beacon.

As ground-based telescopes grow in size the dimensionality of the atmospheric tomography problem increases exponentially. Coupling this with increasingly demanding use-cases for atmospheric tomography, such as for space situational awareness, or for imaging dynamic off-axis targets; the increasing dimensionality of the atmospheric tomography problem poses a problem in terms of computational efficiency. New methods must be employed to either reduce the complexity or dimensionality of the problem without compromising performance.

One method that has been explored is using different basis functions to reduce the dimensionality of the point spread function representations. The most commonly used basis functions for tomographic reproduction are Zernike polynomials. There are growing blocks of research that use wavelets, the related ridgelets, and novel machine learning processes to reduce the complexity of estimation for tomographic reproductions, when compared to Zernike polynomials. Other fields of tomography have used the discrete cosine transform as the basis functions.

In this paper we explore and compare the effects of different basis functions on the performance of tomographic reproduction algorithms, using Shack-Hartmann and Geometric wavefront sensors. Tomographic reproduction performance is evaluated in terms of accuracy, computational/time complexity, noise rejection, and off-axis target performance.

Keywords: atmospheric, tomography, Zernike, dimensionality, comparison, Shack, Hartmann, Geometric, wavefront, sensor, reproduction

*Speaker

†Corresponding author: daniel.hopkins@canterbury.ac.nz