Estimation of Object Spectral Content Using Phase Diversity

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Abstract: We present a method of estimating object spectral content using phase diversity with a grey-world assumption. Operation of a multi-aperture system is simulated, using sub-aperture piston phase diversity.

OCIS Codes: 100.5070 Phase Retrieval; 110.6770 Telescopes; 300.0300 Spectroscopy

1. Introduction

Conventional methods of phase diversity using known focus errors have been applied to monolithic and multi-aperture systems as a means of wavefront sensing and image reconstruction [1,2]. Further work as been done to utilize the unique architecture of multi-aperture systems to introduce known piston errors in some of the sub-apertures as the phase diversity function [3].

More recent work has shown that phase-diversity algorithms can be adapted to account for the broadband nature of many objects of interest [4]. In this paper, we build on this work to estimate system phase errors as well as object spectral content using broadband phase-diversity algorithms.

2. Digital Simulations

Equation (6) in Ref. [4] gives the broadband, grey-world (i.e., spectrally-spatially separable) likelihood metric that is maximized by the phase-diversity algorithm. Digital simulations evaluated the performance of the phase-diversity algorithm in estimating the unknown phase errors, α, and the grey-world spectral coefficients, Φ_λ, simultaneously.

Sub-aperture piston phase diversity was simulated on a tri-arm 9 multi-aperture system. The nature of the diversity was such that for each image, the piston value for each sub-aperture was random, but known. For example, for the first diversity image, the sub-apertures had random piston values between -17.2λ and 10.6λ; for the second diversity image, the sub-apertures had random piston values between -14.6λ and 16.6λ, and so on.

The object used for this study was taken from a set of AVIRIS data [5] and down-sampled to a spectral resolution of 48 nm. A bandwidth of 336 nm around a center wavelength of 1 μm was evaluated. The average simulated wavefront error was approximately 0.30λ RMS of both low-order sub-aperture aberrations and global aberrations including astigmatism, coma and spherical. Photon and read noise were included for an average pixel SNR of approximately 260. We successfully reconstructed, along with the phase errors, the spectral content of the scene, as shown in Figure 1(d).

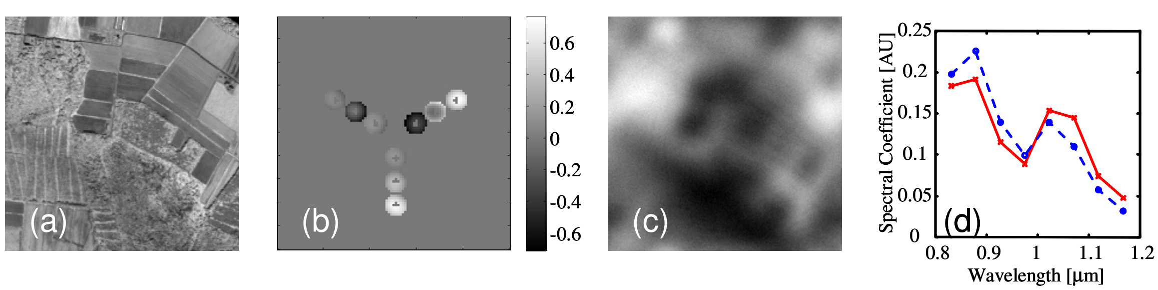

Figure 1 – (a) Example object (single-band), (b) phase map of pupil errors in units of μm OPD, (c) example raw diversity image, (d) average pixel grey-world spectrum (solid line) and estimated grey-world spectrum (dashed line).

3. References

[1] R.G. Paxman and J.R. Fienup, "Optical misalignment sensing and image reconstruction using phase diversity," *J. Opt. Soc. Am. A* **5**, 914 – 923 (1988).
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[3] M.R. Bolcar and J.R. Fienup, "Method of phase diversity in multi-aperture systems utilizing individual sub-aperture control," in *Unconventional Imaging II*, V.L. Gamiz and P.S. Idell, eds., Proc. SPIE **5896** (2005).
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[5] Provided through the courtesy of Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California (http://aviris.jpl.nasa.gov/).