Compact Adaptive Optics

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OMAM Collaborators:

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Introduction

• Compact Adaptive Optics?

Format for this talk:
  – Brief look at existing phase diversity method.
  – Motivation for a more general method.
  – Generalisation
  – Progress to date
  – Conclusions and suggestions for future work
Phase Diverse Wavefront Sensing

• Solution of ITE gives wavefront

\[
\frac{I_{\text{Plane 1}} - I_{\text{Plane 2}}}{z_1 - z_2} \sim \frac{\partial I}{\partial z}
\]

\[
\Psi(r) = -k \int_{R} dr' G(r, r') \frac{\partial I(r')}{\partial z}
\]

• DoE used to image Planes 1 & 2
Diffractive Optics

- Images of different object layers recorded on the same focal plane


- The plane separation and image locations are determined by the properties of the grating
Examples of Data

- Some examples of the data seen at the focal plane.
- Easy to see the aberrations present in the data just by eye.
  - Defocus
  - Astigmatism
  - Coma
  - Trefoil
  - Spherical Aberration

Limitations

• The current Greens’ function solution carries implicit assumptions which limit the wavefront sensor:
  – It is assumed that the input illumination is uniform (i.e. no scintillated wavefronts).
  – It is assumed that the wavefront and its slope are continuous.
  – Dynamic range limitations
Generalisation

- Move away from the physical picture of the 2 defocus method.
- Current method: Convolution with the defocus kernel.
- What about other aberration kernels?
- Limitations?
Generalisation

• Advantages: polishing applications, segmented optics, imaging of silicon circuitry…

Some obvious questions:

– What, if anything, is special about Defocus?
– What generic properties must a filter function possess?
– Can this be optimised so that particular filter functions may be used for particular applications?
Sufficient Conditions

Sufficient conditions are needed to characterise suitable functions for use in a null sensor.

- **Sufficient condition**: the difference between two aberrated images is null if the input wavefront has an Hermitian transform, and non null for non-plane wavefronts.

If \( f(r) \) is real then \( \Im\{f(r)\} \) is Hermitian

i.e. \( F(\xi)=\Im\{f(r)\} \) then \( F(\xi)=F^*(-\xi) \)
Necessary Conditions

- **Necessary condition:** The filter function must be complex. Mixed symmetries of the real and imaginary parts must not be used.

Filter function \( P(\xi) = R(\xi) + iI(\xi) \)

1) \( I(\xi) \neq 0 \); \( R(\xi) \neq 0 \)

2) \( I(\xi) = I(-\xi) \) and \( R(\xi) = R(-\xi) \) [both even symmetry]
   or \( I(\xi) = -I(-\xi) \) and \( R(\xi) = -R(-\xi) \) [both odd symmetry]
Implementation

• A compact adaptive optics system

• SLMs provide modulation.
• DoE combines phase diverse data and corrected image.
• CMOS camera
Data Reduction

- Error Reduction algorithms using FRFT’s and or FFT’s to provide a numerical solution to the data reduction

- Work to continue on an analytic solution.

- Full reconstruction is unnecessary when used as a null sensor for adaptive optics.

- Processing speed/computer power is not an issue in this case.
Further Work

Optimisation:
- Are there optimum filter functions for particular applications?

- Practical tests:
  - Data reduction.
  - Manufacture and testing of customised gratings
Conclusions

• There is a need for a more generalised approach to phase diverse wavefront sensing to overcome the limitations of the current method.

• Necessary and sufficient conditions for a null sensor have been obtained.

• It has been shown that the construction of a compact adaptive optics system using a generalised method is possible.

• Optimisation and experimental testing is to be conducted