



What is the size of the isoplanatic patch in the human eye?

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Introduction

Adaptive optics (AO) systems are used to obtain high resolution images. The two main components of AO systems are, the wavefront sensor and the deformable mirror. Performance of the AO depends on the aberration information we have about the object. For deformable mirrors to compensate and generate clear images over a reasonably large field, aberrations of different locations on the retina have to remain a constant. The goal of this project is to determine the size of the isoplanatic angle, which is that angle the axis passing through the center of the eye makes with the incident beam direction. The size of the isoplanatic patch defines the extents of an image that can be imaged with an adaptive optics system without loss of image quality. Earlier investigations on the isoplanatic patch size have given an estimate of ~ 1 deg¹.

Methods

The instrument we used to measure the aberrations of the eye was the Shack-Hartmann wavefront sensor shown in fig 1. The light source is an 830nm laser beam with incident corneal power of $< 15 \mu\text{W}$. Light from the laser source falls on the retina and point source image is formed. Scattered light from the retina exits the eye and passes through a telescopic relay with a magnification of 0.80. The pupil plane is imaged onto a CCD camera through a lenslet array, effectively breaking the incident wavefront into subapertures. These subapertures create a spot pattern (see fig.2).

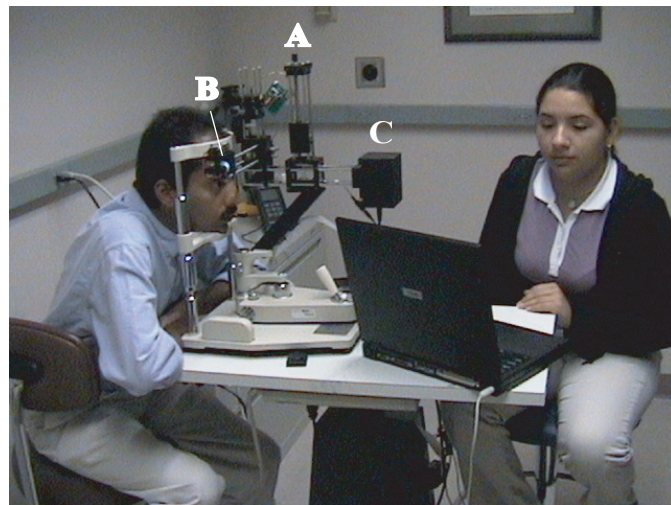


Fig.1: The wavefront sensor used in our experiment is shown in this picture. The source is positioned at A, B is the location of the fixation target, and C is the camera, interfaced to the instrument to obtain the wavefront slope images.

A fixation target was made with circles spaced 1 degree up to 5 degrees. This fixation target had 41 locations starting from the center and extending radially as shown in fig 3. Aberrations were measured at forty-one locations. Change in aberrations with respect to the central location were computed. The exposure time was ~ 30 ms. The wave aberrations were measured for 2 subjects over a 6mm pupil size.

The locations are spaced one degree apart totalling a span of five degrees in the radial direction 'r' and eight evenly spaced locations at every 'r'. At location 0, the incident light maps on axis aberrations. At every location, three wavefront sensor measurements were recorded and averaged.

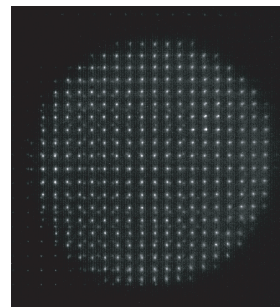


Fig.2: Spot pattern image of a wavefront obtained with the Shack-Hartmann wavefront sensor.

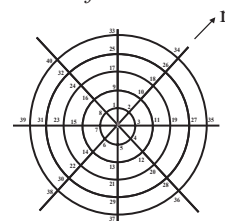


Fig.3: Fixation target used in our experiment. Each circle is spaced 1 degree apart spanning a total of 5 degrees radially from the axis of the incident light and 8 evenly spaced fixation location at every r.

Analysis

Wavefront slope measurements from wavefront sensor (830nm laser source, Power at cornea $\sim 15 \mu\text{W}$)

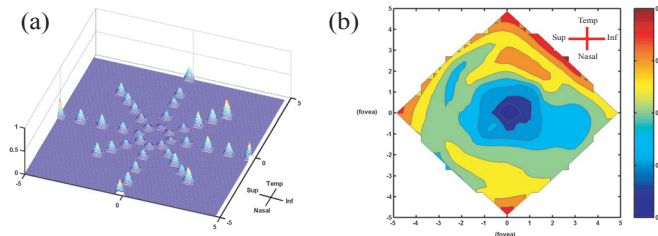
Wavefront analysis:
Pupil size 6mm;
Zernike polynomials

RMS of difference of the Zernike coefficient between i^{th} location and location 0 (on axis) (S)

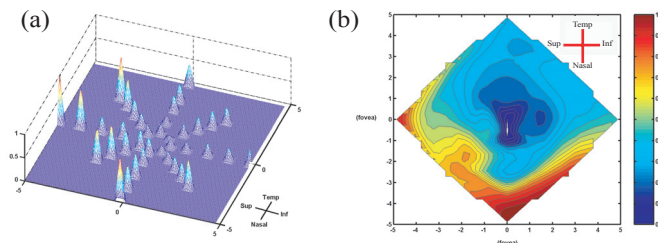
Contour plot drawn by interpolating data using 'S' measured at discrete locations.

Results and Conclusion

The root mean square (RMS) value of the difference of the Zernike coefficients between i^{th} location and location 0 (on axis) is plotted in fig 4. The mean noise level in our measurements is ~ 0.1 microns and this to define the extent of the isoplanatic patch size.



Subject AR:



Subject AZ:

Fig 4:

Plot(a): The RMS of the difference in Zernike coefficients for subject AR, at different locations with respect to central location 0 is shown here. The axis is in degrees of space spanning from the fovea. Symmetrical changes are observed as we radially move from the central location.

Plot(b): Using the measured aberrations at discrete locations we interpolate the data to obtain the contour plot over a 10 deg X 10 deg square region centered around the fovea. The isoplanatic patch is symmetric is ~ 2 deg in size.

Plot(a): The RMS of the difference in Zernike coefficients for subject AZ, at different locations with respect to central location 0 is shown here. It is seen that aberrations are higher in the superior and nasal direction. Asymmetrical changes are seen as we radially move from the central location.

Plot(b): Using the measured aberrations at discrete locations, we interpolate the data to obtain the contour plot over a 10 deg X 10 deg square region centered around the fovea. In the N-T direction the extent of the isoplanatic patch is ~ 2 deg, whereas in the S-I direction, the extent of the isoplanatic patch size is ~ 1 deg.

Isoplanatic angle defines the extent over which AO can compensate for the aberrations effectively. In our experiment, between 2 subjects, we see a considerable difference in the geometry and size of the isoplanatic patch size. For subject AR, the isoplanatic patch size is ~ 2 deg and is symmetrical whereas for subject AZ the isoplanatic patch size is ~ 2 deg in N-T direction and ~ 1 deg in the S-I direction. Analysis of more data will be necessary to determine the general nature of the isoplanatic patch in the human eye.

References

David R. Williams, Junzhong Liang, Donald T. Miller and Austin Roorda (1999), "Wavefront Sensing and Compensation for the Human Eye". In: Adaptive Optics Engineering Handbook (Tyson RK ed), pp 287-310. New York: Marcel Dekker.

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