VS212A Lab Assignment

due: Monday October 12th

In the lab section of this proseminar, we used the Shack-Hartmann wavefront sensor to measure the aberrations of your eyes. I have already analyzed them and fit the wave aberration with a Zernike polynomial function. Your task is to do an analysis of the aberrations of the class as described below. The analysis is to be done using Matlab. I have already written the programs; all you have to do is learn how to use them. The programs, the data and other materials can be found on the BCourses class site.

- To get Matlab programs, download the zip file with the Wavefront Software. Copy the zipped file onto any computer that has Matlab installed and unzip. The main folder contains the Matlab programs that are used for the analysis. The ***images*** folder is one that is used to save outputs from the Matlab programs. The ***ZERfiles_for_5_eyes_over_6mm_pupil*** folder contains some sample files that have the Zernike coefficients. Start by opening and reading UserGuide.doc.
- To get the class aberration data and the lab assignment, download and unzip the file named VS212A_2015_Aberration_Data.zip onto your computer. There are two folders, ***ZER*** and ***IMG***. In the folder ***ZER***, you'll find a set of files for each study participant which contains the coefficients of the Zernike polynomials of the wave aberrations for your maximum pupil size and every integer pupil size below that down to 3 mm. They are text files. You can easily read them into Excel as tab delimited files. In the folder ***IMG,*** you will find Tiff images of the spot patterns for each study participant.

Disclaimer: *Please do not take these data too seriously. The instrument works very well, but we did not make our measurements under ideal conditions. For example, we did not control for the eye's accommodation. If a subject was accommodating, then we would incorrectly interpret it as myopia. Also, although I took several measures, the Zernike coefficients that you will use were drawn from a single measurement (I did check the repeatability for several of you and it was very good).*

Requirements for Lab Report

Introduction

Provide a short introduction to the report

Methods

Summarize the conditions for the measurements. (who had glasses or contact lenses, lighting conditions etc)

Describe briefly (in about 1 page) how a Shack-Hartmann wavefront sensor works.

Results

ignore Bala, he couldn't get a 5mm pupil size...

absolute coefficient (absolute value), (magniute) of zernike coefficients.

For the 16 sets of Zernike coefficients that were computed **over a 5 mm pupil**

- Plot the average and standard deviation for each Zernike coefficient (this is best done by extracting the coefficients from the *.zer file and putting them in an Excel spreadsheet)
- Compute the average RMS as a function of wavefront order (2nd order includes terms 3-5, 3rd order includes terms 6-9, etc) and plot it as a bar graph***. Add standard error of the mean (SEM) to each bar. (****compute the RMS as a function of order for each individual first, then average the results for all 16 individuals, then plot*)
- Compute the high-order RMS (terms 6 and higher) and the Strehl ratio for each subject and put them in a table.
- Print a picture of the high-order wave aberration for each subject
- Print a picture of the PSF for high order aberrations for each subject
- Plot all the radial average MTFs for high order aberrations on a single graph

are you dominated by spherical abberation, coma, or defocus?

Choose three sets of Zernike coefficients (preferably including your own)

- Plot the Strehl ratio and the RMS (on the same plot) as a function of a range of defocus in 0.25 D steps for the aberration over a 5 mm pupil. Be sure to extend the range enough to include the maximum (-1 to +1 should do). DO not include the astigmatism terms in this calculation (ie set c(3) and c(5) to zero.
- Convolve the PSF with 20/20 letters for each of the PSFs computed above.
- Plot the radial average MTFs as a function of defocus state on a single plot. (one plot for each subject)

population statistics, all is average zero, except for average positive Z(4,0) = positive spherical abberation.

For one eye which has a pupil size **of 6 mm or greater** (preferably your own)

- For each pupil size from 6 to 2 in steps of 1 mm, find the defocus level that has the highest Strehl ratio, and plot Strehl vs pupil size.
- Convolve the best PSF (i.e the one with highest Strehl) at each pupil size with a 20/10 letter and show on a single page.
- Plot the radial average MTF at the defocus level that gives the highest Strehl ratio from the maximum pupil size down to 2 mm in 1 mm steps (all on the same plot).

plotting MTF: 1st col is spatial frequency (cycles/degree), second is contrast that gets through. Each file is a different pupil size.

Discussion

For the 12 sets of Zernike coefficients that were computed over a 5 mm pupil

- Are the aberrations random? Explain your answer.
- Which aberration orders are the most deleterious for vision, as quantified by RMS?
- For the 5 mm pupil, who has the highest aberration according to the Strehl ratio? According to the RMS? Are they the same?
- Is the rank of image quality in the subjects the same for Strehl ratio as for RMS?
- Which subject has the highest image contrast image at 15 cycles per degree?

For the three sets of Zernike coefficients with a 5 mm pupil that you selected earlier.

maximizing strell is a better metric for optimizing image quality than minimizing RMS by minimizing refractive error.

light conditions were semi-lit: mesopic

natural pupils - not frozen to cause accommodation - cannot distinguish between accomodation and myopia

- Does the defocus state that gives the maximum Strehl ratio match the defocus state with the minimum RMS?
- Look at the convolved images as a function of defocus. In your opinion, which defocus state generates the most legible image? Comment on the relationships between legibility, Strehl ratio and RMS.
- For the 5mm pupil, at what defocus state is the area under the MTF the greatest?
- For the 5 mm pupil, at what defocus state is the contrast of a 30 c/deg grating the highest?
- Is the best focus state the same for all of the above image quality metrics? Comment on why or why not?

For the one eye with a pupil size of 6 mm or greater.

- For what pupil size is the area under the MTF the greatest?
- For what pupil size is the contrast of a 30 cyc/deg grating the highest? Based on the above results, what pupil size would provide the best acuity for each of the 3 subjects?
- Which pupil size do you think gives the best acuity for a 20/10 letter?

Other questions:

1. Describe properties of the eye that serve to reduce the effects of spherical aberration and chromatic aberration.

2. What diameter telescope would be required to resolve two features (assume point sources) on the moon that are separated by 2 meters? *Assume no atmospheric turbulence causing aberrations, image wavelength of 600 nm and a moon to earth distance of 384,400 km*.

3. The change in refraction of the eye as a function of wavelength is fit by the following equation (from Larry Thibos, Indiana University).

$$\Delta K = 1.68524 - \left(\frac{0.63346}{\lambda - 0.2141}\right)$$, where λ is the wavelength in micrometers.

   Using this equation, determine the placement of three different targets - one blue (440nm), one green (525nm) and one red (630 nm) - such that they are simultaneously in focus on the retina.

tom salmon's paper - our data should be similar to this.

Grading Scheme:

Intro and Methods:	5 pts
Accuracy and Completeness of Results:	10 pts
Thoroughness and Correctness of Discussion:	15 pts
Solutions to Questions:	10 pts
Style:	10 pts
Total:	**50 pts**

Intro and methods have to be informative and in your own words. Points for discussion are awarded for good insight and analysis of results. Style points are awarded for good writing and appearance.