

# **Development of Digital Visualization Tool: Visual Image Simulation (VIS)**

**DigitEyez / Brandon Zimmerman**

This has been approved by our customer (12/14/17)

Project Coordinator: Ali Hashim

Customer Liaison: Diego Martinez

Document Handler: Perry Wang

Scribe: Weidi Liu

Faculty Adviser: Dr. Jennifer Hunter

Document Number 00005

Revisions Level

E

Date

12-14-2017

This is a computer-generated document. The electronic master is the official revision. Paper copies are for reference only. Paper copies may be authenticated for specifically stated purposes in the authentication block.

Authentication Block

00005

Rev E

## Visual Image Simulation (VIS) Description Document

Rev	Description	Date	Authorization
A	Initial PRD	10-27-2017	PBW
B	PRD 2	11-16-2017	AH
C	PRD 3	11-30-2017	DAM
D	PRD 4	12-12-2017	AH
E	PRD 5	12-14-2017	AH

# Visual Image Simulation (VIS) Description Document

<b>Vision</b>	<b>3</b>
<b>Environment</b>	<b>4</b>
Programming Language	4
Operating Conditions	4
<b>Fitness for use</b>	<b>5</b>
Visual Image Simulation Tool	5
Non-responsibilities	5
Timeline	6
It is desirable that	7
If there is time/resources	8
<b>References</b>	<b>8</b>
<b>Appendix</b>	<b>8</b>
<b>Special Thanks</b>	<b>9</b>
<b>Customer Approval</b>	<b>10</b>

## Visual Image Simulation (VIS) Description Document

The Vision Image Simulation tool is a software tool that will be used in conjunction with DigitEyez's proprietary algorithm spearheaded by Brandon Zimmerman and will be developed with the help of our faculty advisor, Dr. Jennifer Hunter.

### **Vision:**

The vision for this project is to develop a digital visualization tool for DigitEyez to simulate how a patient's eyes will subjectively perform in a routine eye exam. The goal is to be able to use this tool to assist in digitally providing accurate prescriptions for eye-care while reducing the time, cost, and human error currently associated with this common exam routine. The Visual Image Simulation (VIS) tool will specifically aid ophthalmologists and optometrists to give more accurate prescriptions, whereas other visual acuity apps on the market are only used by the consumer. The VIS tool will be used in conjunction with DigitEyez's proprietary algorithm, which aims to directly determine the ideal prescription of the patient using only autorefractor measurements within  $\frac{1}{4}$  of a diopter. The patient's subjective feedback from using the VIS tool will be used to confirm that the predicted prescriptions are correct, or that the prescriptions need to be modified to adequately correct the patient's vision.

### **Team Responsibilities:**

Ali Hashim: Project Coordinator, MATLAB Programmer, iOS Programmer

Diego Martinez: Customer Liaison, MATLAB Programmer, Code V Programmer

Perry Wang: Document Handler, MATLAB programmer, Code V programmer

Weidi Liu: Scribe, MATLAB programmer, Code V programmer

### **Environment:**

Programming Language:

- MATLAB
  - Programming language for VIS tool
- Code V
  - An eye model will be produced to compare the point spread function (PSF) obtained from our VIS tool to real ray tracing

Operating Condition:

- Assume that the images will be simulated for a patient's vision at room temperature and normal humidity
- Initially, a wavelength of 555 nm will be used because the average human eye has the most spectral sensitivity at this wavelength

## Visual Image Simulation (VIS) Description Document

- To make the VIS polychromatic, we will use the spectral luminous efficiency to weigh the different wavelengths to obtain a polychromatic PSF
- The patient's vision that will be simulated will be from 20 ft away from the image

### **Regulatory Issues:**

There are no regulatory issues that we will need to consider for our project. If paperwork is needed to test how DigitEyez's algorithm performs in conjunction with our visual image simulation tool, it will be handled by the customer.

### **Fitness for use:**

The Visual Image Simulation tool will:

- Use the data obtained from autorefractor measurements and from DigitEyez's algorithm to conduct a Huygen's-Fresnel propagation.
- Use the Huygen's-Fresnel propagation through the eye along with a numerical ray trace to determine the amplitude and phase of the corrected and uncorrected field at the image plane of the human eye. The phase of the PSF will be calculated based on the Zernike polynomials that describe the human cornea, while the amplitude will be described by the individual toric nature of each patient's cornea. The main Zernike polynomials will be spherical aberration, astigmatism and defocus.
- Use the PSF calculated from the Huygen's-Fresnel propagation and convolve it with the source image to produce the patient's retinal image.
- Simulate the patient's view of a sample image with and without prescription glasses.
  - Ophthalmologists will rely on subjective patient feedback from the VIS tool to either confirm the prescriptions are adequate, or that the prescriptions need to be modified for the patient's vision.
- Image each eye individually.
- Additionally be used to simulate a patient's vision of gradient Snellen letters developed by DigitEyez and Ben Vision Research.

## Visual Image Simulation (VIS) Description Document

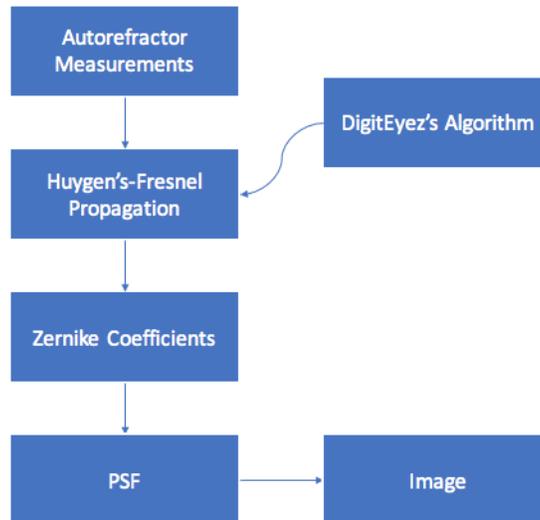


Figure 1: System diagram depicting the basic steps that will be carried out by the visual image simulation tool. The autorefractor measurements and DigitEyz's algorithm will be used to propagate through the eye and the phase accumulated at each surface will describe the wavefront error of the patient's vision. The phase will be used to calculate the PSF and the PSF will be convolved with the source image to give the retinal image of the patient. These steps will be repeated for each eye and with the predicted prescription outputted from DigitEyz's algorithm.

What we are not responsible for:

- Determining the prescription for a patient.
- Paperwork for conducting a test run with an optometrist using the final product.
- The numerical ray trace.

### **Timeline:**

During the fall semester we:

- Used Zernike coefficients from Watson's paper, "Computing Human Optical Point Spread Functions" to compute the PSF and convolved it with a target image to produce a retinal image using a circular pupil.
- Produced an optical design of the Gullstrand eye model in Code V using spherical surfaces.

## Visual Image Simulation (VIS) Description Document

During the spring semester we will:

- Take into account the apodization of the eye to mimik the Stiles-Crawford effect at the retina.
- Conduct a Huygen's-Fresnel propagation through the eye to determine both amplitude and phase at the image plane.
- Make the VIS polychromatic and take into account chromatic aberrations (Polychromatic PSF).
- Use DigitEyez's algorithm to obtain the Zernike polynomials for the aberrated eye based on the individual patient.
- Produce a gradient index model of the human eye in Code V to compare with the PSF produced from the VIS tool in Matlab.
- Account for the toric nature of the cornea by using an elliptical pupil function instead of a circular pupil function.

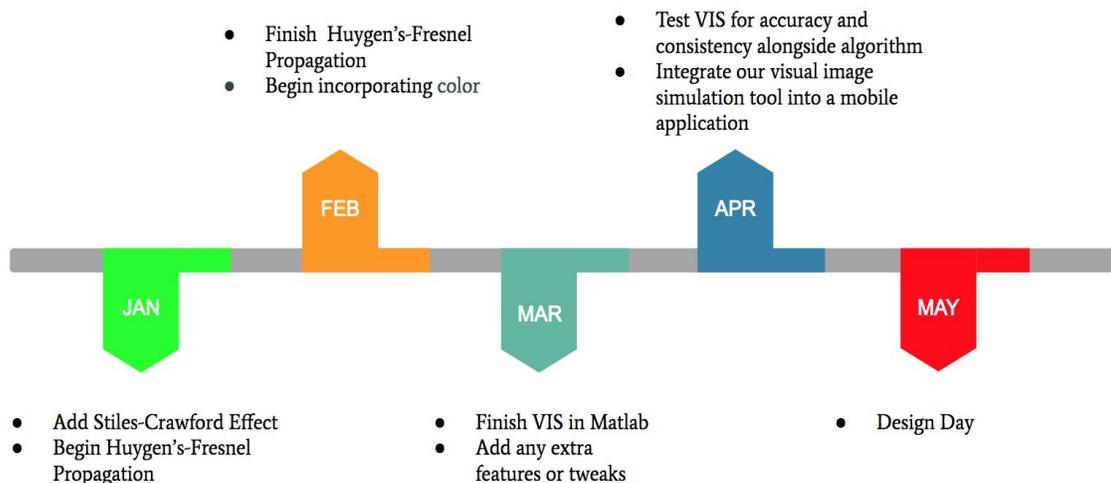


Figure 2: Timeline demonstrating when we intend on completing each deliverable.

It is desirable that:

- There will be no cost for this project.
- Polychromatic PSFs will be produced and chromatic aberrations will be accounted for.
- The only data obtained from an eye exam is the autorefractor measurements.
  - Color blindness, eye pressure, and retinal scan data can be used if needed

## Visual Image Simulation (VIS) Description Document

- Code V will be used to model the eye and output a PSF to compare with the results from the VIS tool.
- A test run with an optometrist will be conducted with the final product. Team Vision will serve as the patients, and will determine if the algorithm and VIS tool together can match the subjective prescription of each patient that the optometrist prescribes.

If there is time and/or team resources available:

The visual image simulation tool will:

- be integrated into a mobile app
- include a user-friendly GUI

We will also contribute to the proprietary algorithm time permitting.

### References:

Iskander, D. Robert, et al. "Objective Refraction from Monochromatic Wavefront Aberrations via Zernike Power Polynomials." *Ophthalmic and Physiological Optics*, vol. 27, no. 3, 2007, pp. 245–255., doi:10.1111/j.1475-1313.2007.00473.x.

Watson, Andrew B. "Computing Human Optical Point Spread Functions." *Journal of Vision*, The Association for Research in Vision and Ophthalmology, 1 Feb. 2015, [jov.arvojournals.org/article.aspx?articleid=2213266](http://jov.arvojournals.org/article.aspx?articleid=2213266).

Huang, Yanqiao. "Human Lens Modeling and Biometric Measurement Technique." Department of Biomedical Engineering, University of Rochester. 2008. <http://hdl.handle.net/1802/6275>

### Appendix:

*Equations:*

$$w(x', y') = \sum_{n, m} c_n^m z_n^m(x', y') \quad (1)$$

where  $w(x', y')$  is the wavefront error function, which can be determined by summing up the Zernike polynomials with a given order  $n$ , given frequency  $m$ , and weighting coefficient  $c$ .

$$g(x', y') = p(x', y') \exp(i(2\pi/\lambda) w(x', y')) \quad (2)$$

where  $g(x', y')$  is the generalized complex pupil function,  $p(x', y')$  is the pupil, and  $\lambda$  is the wavelength.

$$h(x, y) = \|F[g(x', y')]\|^2 \quad (3)$$

where  $h(x, y)$  is the PSF for incoherent light. It is given by the squared modulus of the Fourier transform of the generalized pupil function.

## Visual Image Simulation (VIS) Description Document

$$r(x, y) = h(x, y) * s(x, y) \quad (4)$$

where  $r(x, y)$  is the retinal image function. It is the convolution of the source image  $s(x,y)$  and the PSF.

*Preliminary Results:*



**Figure 3:** Image taken from our current Matlab algorithm depicting a source image on the left and a retinal image on the right using hard coded zernike polynomials and a circular pupil.

We have also started manipulating a Code V model of the eye for comparison with the PSF's produced from the VIS tool. We have also started a simple iOS application, that can be easily integrated with our VIS tool to display the images on an iPhone or iPad.

### **Special Thanks to:**

Brandon Zimmerman - Customer

Jennifer Hunter - Faculty Advisor

Wayne Knox - Senior Design Professor

Len Zheleznyak - Image Simulation Advice

James Fienup - Fourier Optics Advice

Anthony Visconti - Gradient Index Modeling in CODEV

# Visual Image Simulation (VIS) Description Document

## Customer Approval:



**Brandon Zimmerman**

to me, Diego, Perry, Weidi ▾

As of today, Dec 14, I have read and approved the current state of the PRD



BZ