DESIGN OF GAUSSIAN SPATIAL FILTER TO DETERMINE THE AMOUNT OF REFRACTION ERROR IN HUMAN EYE

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Abstract

The subjective method of eye testing (Myopia/Hyperopia) involves the communication between the optometrist and the Patient. Communication about the vision/clarity of an eye chart, which the Patient experiences, to the Optometrist and the communication which the Optometrist does to Patient would decide the final prescription. Though the Optometrist is expert in communication, if the Patient gives incorrect responses, it leads to inaccurate prescription.

To overcome the above problem, the idea is to develop a novel eye testing method called "Patient Subjective Eye Testing (PSET)", in which a Myopia/Hyperopia Patient interacts with a software application installed on a tablet. A standard eye chart is projected on to a screen. A similar eye chart is also displayed on the tablet. Now the Patient blurs the eye chart that is displayed on the tablet device by applying power in the units of 0.0625 diopters until he/she experiences no difference in the blurness of the optotypes in the projected chart and the displayed chart. The power is recorded and written in to prescription.

For the realization of the above method, a Gaussian spatial filter is designed, which blurs the optotypes of the displayed eye chart similar to the blurness experienced in human eye. To design the filter, the amount of Gaussian blur per unit refraction error in human eye is determined by designing a human eye model using ZEMAX tool. For every unit of 0.0625 diopters (in the range -2 diopters to +2 diopters) change in refraction power of the eye the amount of deviation in Gaussian energy distribution, on the retina, is determined. With these deviation values Gaussian masks are generated which are used by Gaussian filter to blur the eye chart images that are displayed on a tablet device.

Keywords— *Gaussian mask, Blur, Zemax, Myopia, Hyperopia.*

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1. INTRODUCTION

1.1Refraction Problems in Eye

Blur is the subjective experience or perception of a defocus aberration within the eye. Blur may appear differently depending on the amount and type of refractive error. The following are some examples of blurred images that may result from refractive errors of eye. Myopia and Hyperopia causes the image to be appear blurred.

1.2 Myopia

Myopia commonly known as being nearsighted (American English) and shortsighted (British English).A condition of the eye where the light that comes in does not directly focus on the retina but in front of it As shown in Figure 1.2.1. This causes the image that one sees when looking at a distant object to be out of focus but in focus when looking at a close object. Eye care professionals most commonly correct myopia through the use of corrective lenses, such as glasses or contact lenses. The corrective lenses have a negative optical power (*i.e.* are concave) which compensates for the excessive positive diopters of the myopic eye [3].

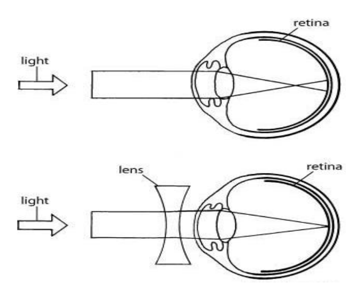

Figure 1.2.1 Myopia

1.3 Hyperopia

Hyperopia, also known as farsightedness, long-sightedness or hypermetropia, is a defect of vision caused by an imperfection in the eye, causing near objects appear blurred. The light that comes in does not directly focus on the retina but behind of it as shown in Figure 1.3.1. The corrective lenses have a positive optical power (*i.e.* are concvex) which compensates for the excessive negative diopters of the hyperopic eye.

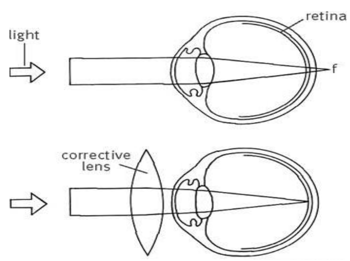

Fig 1.3.1 Hyperopia

2. OBJECTIVE EYE TESTING

The current objective systems for finding the refractive error in human eye are [8]

- Auto Refractor
- Retinoscopy

2.1 Auto Refractor

Auto refractor is a computer-controlled machine used during an Eye examination to provide an objective measurement of a person's Refractive error and prescription for glasses or contact lens. Automated refraction is particularly useful when dealing with non-communicative people such as young children or those with disabilities**.** The automated refraction technique is quick, simple and painless. After application of a cycloplegic agent to keep the ciliary muscle in relaxed position and avoid the erroneous diagnosis of a pseudomyopia, the patient takes a seat and places their chin on a rest. One eye at a time, they look into the machine at a picture inside. The picture moves in and out of focus as the machine takes readings to determine when the image is on the retina. Several readings are taken which the machine averages to form a prescription. No feedback is required from the patient during this process. Within seconds an approximate measurement of a person's prescription can be made by the machine and printed out or shared electronically with an Automated Refraction System.

Fig 2.1.1 AutoRefractor

2.2 Retinoscopy

Retinoscopy is a technique to obtain an objective measurement of the refractive error of a patient's eyes. The examiner uses a retinoscopy as shown in the below Figure 2.6.2 to shine light into the patient's eye and observes the reflection (reflex) off the patient's retina. While moving the streak or spot of light across the pupil the examiner observes the relative movement of the reflex then uses a phoropter or manually places lenses over the eye (using a trial frame and trial lenses) to "neutralize" the reflex.

Fig 2.2.1 Retinoscopy

Retinoscopy is a technique to obtain an objective measurement of the refractive error of a patient's eyes. Retinoscopy is particularly useful in prescribing corrective lenses for patients who are unable to undergo a subjective refraction that requires a judgment and response from the patient.

SUBJECTIVE EYE TESTING

3.1 Phoropter

A phoropter is an instrument commonly used by eye care professionals during an eye examination, containing different lenses used for refraction of the eye during sight testing, to measure an individual's refractive error and determine his or her eyeglass prescription. Phoropter is shown in the below Figure 2.5.1

Fig 3.1.1 Phoropter

Typically, the patient sits behind the phoropter, and looks through it at an eye chart placed at optical infinity (20 feet or 6 meters), then at near (16 inches or 40 centimeters) for individuals needing reading glasses. The eye care professional then changes lenses and other settings, while asking the patient for subjective feedback on which settings gave the best vision.

The lenses within a phoropter refract light in order to focus images on the patient's retina. The optical power of these lenses is measured in 0.25 diopter increments. By changing these lenses, the examiner is able to determine the spherical power, cylindrical power, and cylindrical axis necessary to correct a person's refractive error. The presence of cylindrical power indicates the presence of astigmatism which has an axis measured from 0 to 180 degrees away from being aligned horizontally.

Phoropters are made with either plus or minus cylinders. Traditionally, ophthalmolgists and orthoptists use plus cylinder phoropters and optometrists use minus cylinder phoropters. The phoropters also include prismatic lenses which are used to analyze binocular vision and treat orthoptic problems.

4. THE PROPOSED PSET METHOD

4.1 PSET System Hardware and Software Requirements

The “Patient Subjective Eye Test (PSET)” system requires

1. A 7˝ inches or 10˝ inches Tablet having 1280*800 display resolution and running Android 4.0 or above.
2. A Projector to project standard eye charts on to a screen.
3. An “I-Tester” and OpenCV Manager Android applications installed on the Tablet.

4.2 PSET Procedure for Myopia

Test one eye at a time. Start with the right eye, covering the left one without pressing on it. Then, examine the left eye by doing the opposite.

1. A standard eye chart is projected on to a screen which is in front of the customer at 3 meters distance.
2. The tablet is kept in front of the customer at 1 meter distance. The Tablet is operated through a Bluetooth mouse.
3. The I-Tester application is invoked. The application start screen contains image icons of different eye charts.
4. The Optometrist instructs the customer to click on an appropriate eye chart.
5. The selected eye chart is displayed along with positive , negative power buttons and a slide bar.
6. Now the Optometrist instructs the customer to blur the optotypes in the eye chart that is displayed on the tablet device by applying positive power in the units of 0.0625 diopters until the customer experiences no difference in the vision /clarity of the optotypes in the projected chart and the displayed chart.
7. The customer stops applying power at the point when he/she does not find difference in the vision /clarity of the optotypes in the projected chart and the displayed chart.
8. The Optometrist records the power value and the negative of it is written in to the prescription.

Hence the spherical power is determined for Myopia.

4.3 PSET Procedure for Hyperopia

Test one eye at a time. Start with the right eye, covering the left one without pressing on it. Then, examine the left eye by doing the opposite.

1. A standard eye chart is kept in front of the customer at 16 inches distance.
2. The tablet is kept in front of the customer at 1 meter distance. The Tablet is operated through a Bluetooth mouse.
3. The I-Tester application is invoked. The application start screen contains image icons of different eye charts.
4. The Optometrist instructs the customer to click on an appropriate eye chart.
5. The selected eye chart is displayed along with two push down buttons to apply positive or negative power.
6. Now the Optometrist instructs the customer to blur the optotypes in eye chart that is displayed on the tablet device by applying negative power in the units of 0.0625 diopters until the customer experiences no difference in the vision /clarity of the optotypes in the original chart and the displayed chart.
7. The customer stops applying power at the point when he/she does not find difference in the vision /clarity of the optotypes in the projected chart and the displayed chart.
8. The Optometrist records the power value and the +ve of it is written in to the prescription.

Hence the spherical power is determined for Hyperopia.

5. IMPLEMENTATION AND RESULTS

For the realization of the PSET method, a Gaussian spatial filter is designed, which blurs the optotypes of the displayed eye chart similar to the blurness experienced in human eye. To design the filter, the amount of Gaussian blur per unit refraction error in human eye is determined by designing a human eye model using ZEMAX tool. For every unit of 0.0625 diopters (in the range -2 diopters to +2 diopters) change in refraction power of the eye the amount of deviation in Gaussian energy distribution, on the retina, is determined. With these deviation values Gaussian masks are generated which are used by Gaussian filter to blur the eye chart images that are displayed on a tablet device.

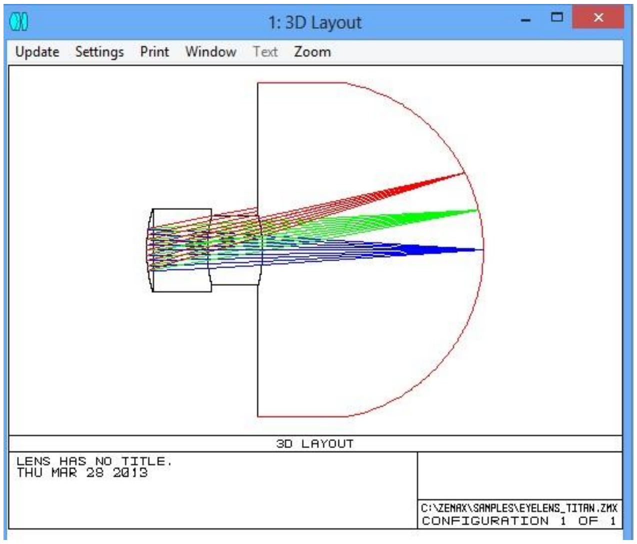

Fig 5.1 Eye model without any power consists of Corenea, Lens, Globe, Retina.

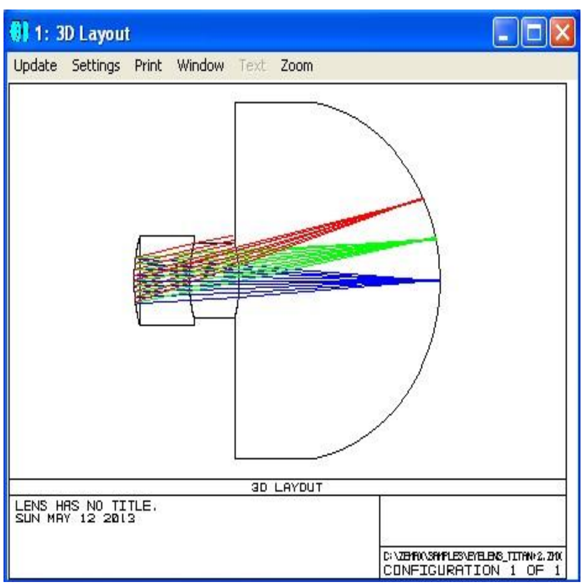

Fig 5.2: 3D Layout of eye for +0.25diopers positive power.

The Figure 5.2 Describes the eye model with +0.25 diopters positive lens power consists of Corenea, Lens, Globe, Retina.

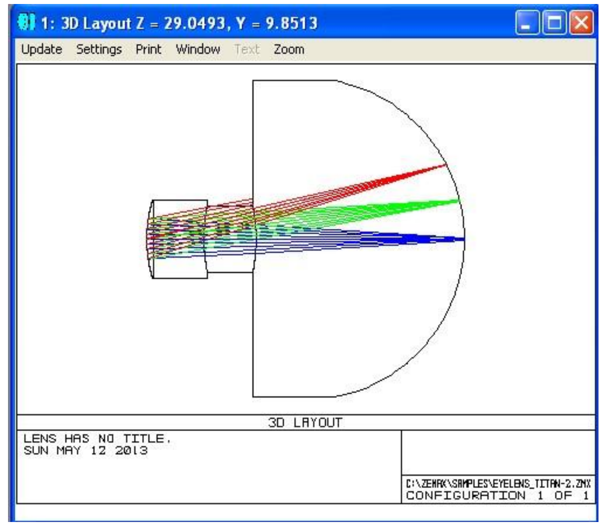

Fig 5.3: 3D Layout of eye for -0.25 diopters Negative power

The Figure 5.3 Describes the eye model with Negative lens power consists of Cornea, Lens, Globe, Retina.

The amount of deviation in Gaussian energy distribution, on the retina, for every unit of 0.0625 diopters (in the range -2 diopters to +2 diopters) change in refraction power of the eye is recorded.

Diopter	Sigma
-2	14.05578759
-1.9375	13.64856802
-1.875	13.14289976
-1.8125	12.72285203
-1.75	12.24850835
-1.6875	11.81533413
-1.625	11.37589499
-1.5625	10.92959427
-1.5	10.47702864
-1.4375	10.01760143
-1.375	9.551312649
-1.3125	9.130966587
-1.25	8.704952267
-1.1875	8.218973747
-1.125	7.781026253
-1.0625	7.337112172
-1	6.887231504
-0.9375	6.431384248
-0.875	5.969570406
-0.8125	5.560859189
-0.75	5.088305489
-0.6875	4.670346062
-0.625	4.187947494
-0.5625	3.762231504
-0.5	3.333830549
-0.4375	2.904534606

-0.375	2.476431981
-0.3125	2.054295943
-0.25	1.64826969
-0.1875	1.32875895
-0.125	1.0325179
-0.0625	1.01625895
0	1
0.625	1.290274463
0.125	1.626491647
0.1875	2.00477327
0.25	2.408412888
0.3125	2.829355609
0.375,	3.263126492
0.4375	3.707338902
0.5	4.160501193
0.5625	4.622016706
0.625	5.012529833
0.6875	5.488066826
0.75	5.970763723
0.8125	6.378878282
0.875	6.874701671
0.9375	7.293556086
1	7.802505967
1.0625	8.145883055
1.125	8.66676611
1.1875	9.01849642
1.25	9.551610979
1.3125	10.00178998
1.375	10.4573389
1.4375	10.91825776
1.5	11.38424821
1.5625	11.85590692
1.625	12.33323389
1.6875	12.71927208
1.75	13.20674224
1.8125	13.700179
1.875	14.09934368
1.9375	14.50208831
2	15.01103819

A plot is drawn between amount of deviation in Gaussian energy distribution, on the retina, for every unit of 0.0625 diopters (in the range -2 diopters to +2 diopters) change in refraction power of the eye.

The plot in figure 5.4 illustrates that as the negative power of eye increases the amount of deviation in Gaussian energy distribution, on the retina, is decreasing. As the positive power of eye increases the amount of deviation in Gaussian energy distribution, on the retina, is increasing.

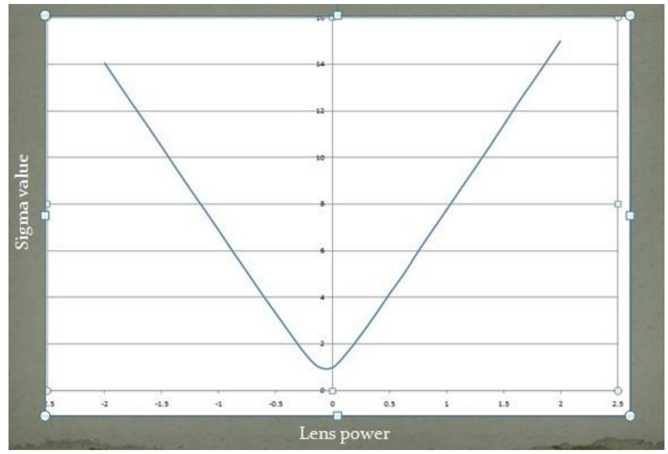

Fig 5.4 Plot Lens power Vs Sigma Values

Gaussian mask (5X5) for different sigma values:
Gaussian masks of size 5*5 are generated for all the negative and positive powers by substituting respective sigma value in the following Matlab code. These masks are applied on the Snellen chart to realize the blurness experienced in human eye.

m=5; n=5;

Sigma=0.022;

[h1,h2]=meshgrid(-(m-1)/2: (m-1)/2,-(n-1)/2: (n-1)/2);

hg=exp(-(h1.^2+h2.^2)/(2*sigma^2));

h=hg./sum(hg(:))

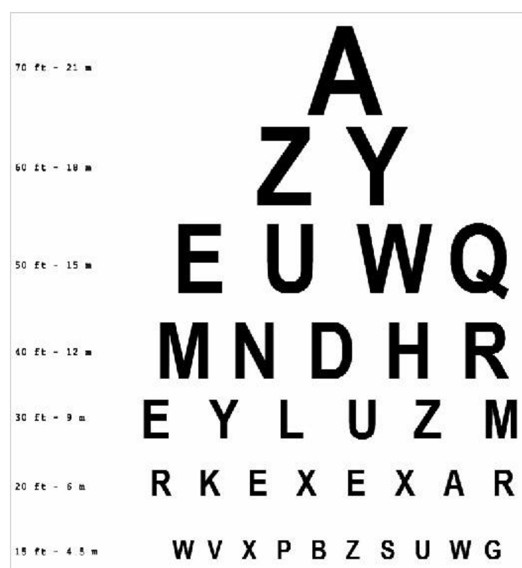

Fig 5.6 Original Image of Snellenchart

Fig 5.7 Image blur with 0.25diopters

6. CONCLUSIONS

We conclude that our proposed eye testing method improves the optometrist work efficiency and patient's satisfaction. The communication between optometrist and patient is minimized and accuracy of the prescription is maximized. The cost of eye test can also be reduced.

Using subjective process of estimating blur per unit lens power is more accurate than current objective process. With the subjective process the patient interaction is more, so that less chances of dissatisfaction among patient with doctors prescription.

Productivity of the optometrist can be increased. Training to the new optometrists can make easy.

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