

Analysis of blue light pixels for detection of preferred retinal locus.

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Abstract

Detection of 'Preferred Retinal Locus' (PRL) in human eyes is one of the important tests during clinical assessment for treatment of certain retinal lesions. Significance of blue light has been analyzed in this paper using simple image processing algorithm in detecting PRL. Fundus photographs of 19 patients, (eleven normal and eight central retinal lesions) were taken for the analyses of RGB pixel intensities. Along with Red Maximum (Rmax), Green Maximum (Gmax) and Red Green maximum (R + Gmax), Blue Minimum (Bmin) pixel intensity values were also obtained for all the images. Blue pixel values were found to be minimum in fovea for all 100% of the normal retinal images. For PRL retinal images, Bmin method matched the location in 88% of images. This method signifies that the analysis of blue light for patients with eccentric fixation is a good alternative compared to scanning laser ophthalmoscope (SLO) and microperimetry.

Keywords: Retina, preferred retinal locus, eccentric fixation, image processing.

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Introduction

Capturing the pictures from human retina using a fundus camera, involves a constant light that would be flashed. This light gets reflected from the retina and gets captured at the exit pupil of the human eye. Although a constant flash of light is being sent into the retina, the light reflected from it is not constant and it varies from central fovea to peripheral retina. There are various explanations for this variation e.g., the presence of blood vessels, thickness differences in the retina etc. These variations in the color can be clearly seen in the fundus photographs. Usually the universal color coding of any image is based on CIE RGB color space [1-3]. Possible reasons in this variation of color in the retinal images can be attributed to the absorption and reflectance spectrum of the photoreceptor cells. It was reported earlier [4] that this absorption and reflectance values vary for each wavelength. This variation in both absorption and reflectance exists for all four types of photoreceptors cells (L, M, S cones and rods) and hence the reflected picture of the fundus is a combination of the reflectance from all the four photoreceptors cells. We have hypothesized earlier [5] that a color pixel intensity map taken from the fundus pictures corresponds to the respective area of photoreceptors present in the retina. A single point or coordinate on the fundus picture is the result of combined effect of numerous photoreceptors (reflections) present in the corresponding retina, giving rise to different pixel intensities. This led to develop a new technique in spotting the area of maximum retinal sensitivity. It is an established fact that the fovea has the maximum retinal sensitivity in the human retina. Hence we proposed to analyze the RGB pixel intensities in fovea along with the entire retina. The presence of L cones and M cones in the fovea are well known and there are no S cones and hence called a "No S cone/blue cone Zone". This knowledge of "no blue cones in the fovea", triggered the idea that the presence of blue pixel intensity would be minimum and the

presence of red and green pixel intensities would be maximum in the foveal region. But our hypothesis of "Blue minimum pixel intensity" corresponds well to maximum retinal sensitivity rather than red or green pixel intensities as red and green is also seen in the optic disc. Hence for our algorithm, we proposed to develop Blue minimum (B min), Red maximum (R max), Green Maximum (G max) and Red + Green maximum (R+ G max) to find out the maximal retinal sensitivity in the fundus pictures. Apart from finding out the maximal retinal sensitivity in the normal human retina, this technique will be helpful in finding the "Preferred Retinal Locus" (PRL). The PRL is also called as pseudo fovea and represents an area in the retina which is used for visual tasks when a central macular scotoma affects the patient's central vision. These patients develop PRL or eccentric fixation for best viewing which is a non-fovea region. This kind of shift in the maximal retinal sensitivity from fovea to pseudo fovea is termed as PRL [6,7]. But clinically to find out a PRL would require using laser scanning instruments [8,9]. Which are very expensive, difficult to perform and time consuming in the detection of PRL. Because of the fact that there are no S cones in the fovea [10] the foveal reflectance of blue will be minimum. Hence our work involves in studying this blue light in the fovea as well as in the entire retina by finding out blue minimum pixel intensity in the retinal image, which in turn would be helpful in finding out the maximal retinal sensitivity.

Methods

A total of 19 retinal images were taken for this study to analyze the color pixel intensities. Eleven normal retinal images were selected randomly 4 images from the Internet, Google images and 7 images from FFA (Fundus Fluorescein Angiography) department, retina clinic at Sankara Nethralaya, Chennai were selected. Eight abnormal retinal images with central retinal lesions were taken to find out PRL [7]. Out of eight, two were from the public domain images and six from the retina clinic.

The reasons for selecting the public domain images were to test the proposed method under various situations, such as varying illumination and acquisition conditions like clusters of red lesions which may have the same characteristics of the fovea region, and other artifacts. Although there were various techniques [11-15] reported earlier in automatic detection of the fovea, we identified the foveal region clinically by a well experienced Ophthalmologist. Later a MATLAB algorithm was developed for normal retinal images to analyze pixel intensities at fovea. Then, red, green and blue intensities were separated from the RGB color image for further processing. Using another algorithm, maximum pixel intensities for red (Red Maximum; R max) and green (Green Maximum; G max) were obtained for all images. The minimum pixel intensity for blue was obtained for all images and is termed as Blue Minimum (B min). The number of pixels for B min was also noted. As per the earlier

studies [16-18], reflectance was estimated as r/r_{max} , g/g_{max} and b/b_{max} where r, g and b were red green and blue pixel intensities. In our work, we used the same formula to find out the reflectance of fovea and the entire retina, unlike a single pixel as in earlier works. The age and Log MAR visual acuities of the patients whose images obtained from the retina clinic were also noted for further analyses. A sample of RGB pixel intensity line scan drawn along the x – axis passing through fovea and optic disc is shown in Figure 1. In this line scan RGB pixel intensity peaks at optic disc and falls at fovea and is seen as a depression. The same foveal depression is also seen along y axis in Figure 2. Figure 1 and Figure 2 gives an idea about the possible presence of many R min and G min values along x and y axis. This observation too signifies that finding out B min is more significant than R max and G max for maximal retinal sensitivity as there is no optic disc region. The blue minimum

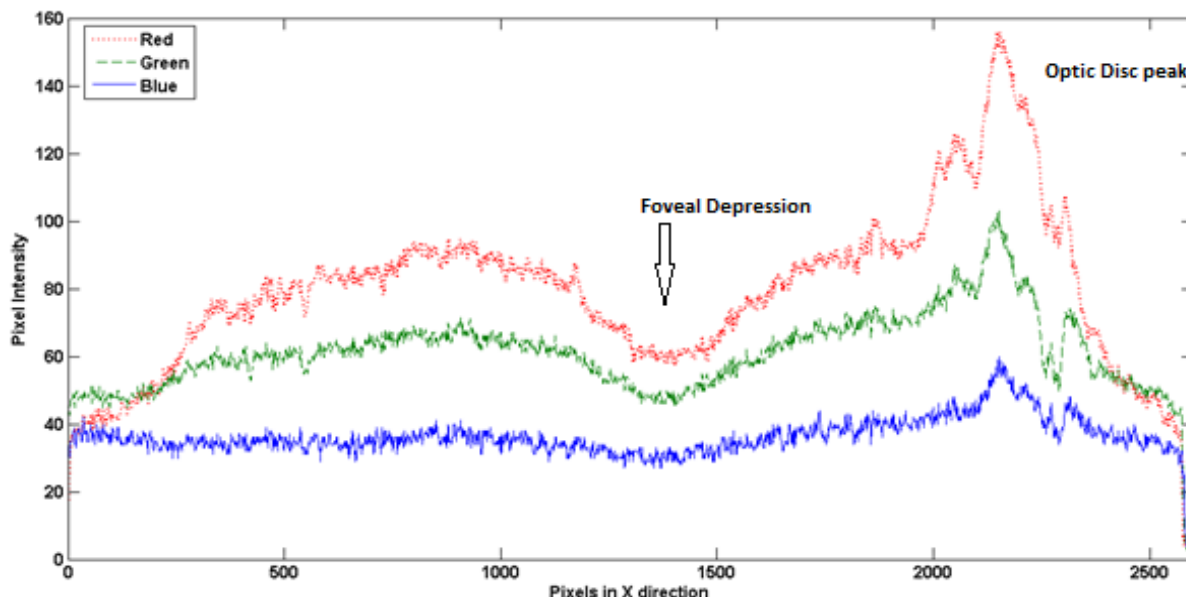


Figure 1: A line scan of RGB pixel intensity values along X axis with optic disc and fovea.

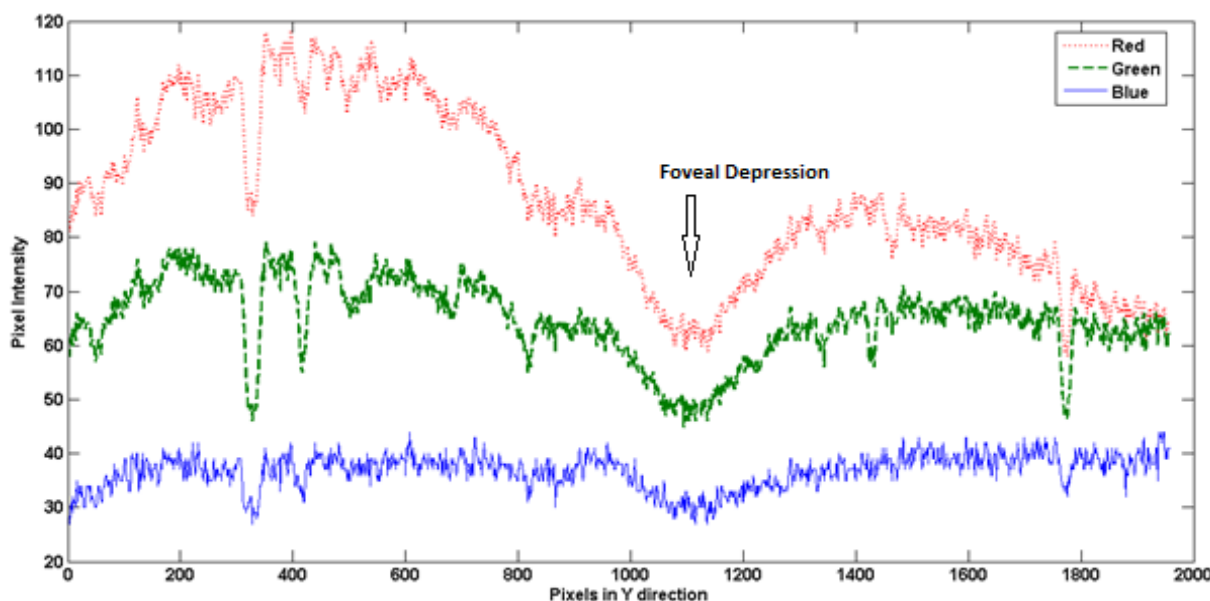


Figure 2: A line scan of RGB pixel intensity values along Y axis with fovea and no optic disc.

location was identified along with number of pixels. Figure 3 shows the location of B min along with the R and G values at that location from public domain images with and without median filtering respectively. Figure 4 shows the location of B min along with the R and G values at that location from retina clinic. Median filtering was done to enhance its location and to ascertain the number of blue minimum point's location. This procedure was repeated for all the retinal images and their respective pixel intensity values were noted. For the normal retinal images obtained from the retina clinic, we had included the patient's age, visual acuity along with the diagnosis for data analysis (Figure 5).

We proposed the following three methods for detecting Preferred Retinal Locus in patients with central retinal lesions.

Discussion

Statistical analysis: Data consisting of age, visual acuity and reflectance were statistically analyzed. Independent T-test and correlation tests were mainly used to analyze the data. In this

work, we had taken the significance level at 95% and p value was fixed at 0.05.

Results and Discussion

In all the eleven normal retinal images, B min location before and after median filtering were found to be 100% in the fovea as shown in Figure 6. This may be an indication that B min corresponds to the maximal retinal sensitivity. Similarly the location of R max and R+G max was found to be 100% in the Fovea. The RGB ratios and reflectivity ratios of all eleven normal retinal images were measured for fovea as well as entire retina and is represented in Table 1. In earlier studies [19], the L, M and S cone density ratio was given as 6: 3: 1, whereas the response ratios for the RGB pixel intensities in this work for public domain images and retina clinic images at fovea were found to be 9: 3: 1 and 2.4: 1.6: 1 respectively. For the entire retina, the response ratio for the RGB pixel intensities for public domain images and retina clinic images were found to be 4: 2: 1 and 2: 1: 4 respectively. Similarly reflectivity for

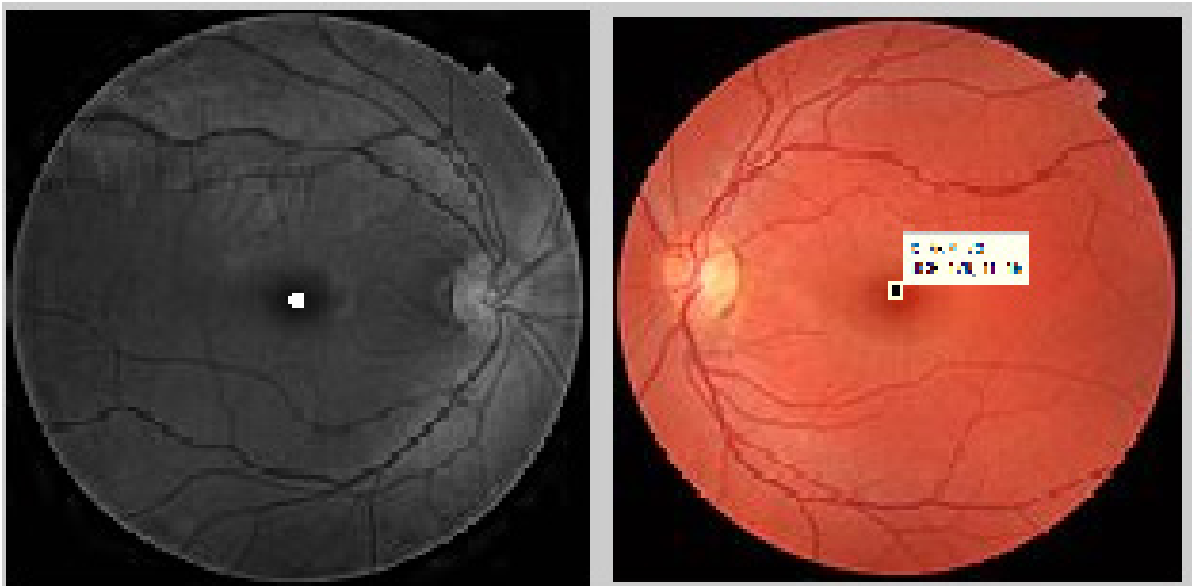


Figure 3: Location of RGB pixel intensities at Fovea with and without median filtering.



Figure 4: R_{max} , G_{max} and B_{min} pixel intensity values at Fovea from our retina clinic.

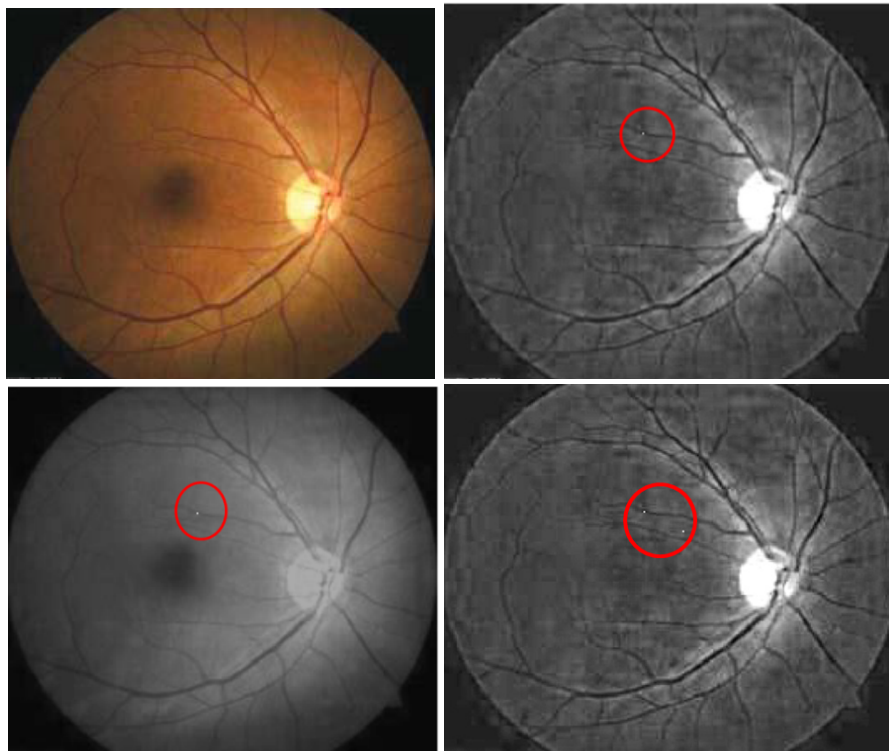


Figure 5: A Dengue retina (before filtering) showing all three methods and the number of pixels found. a) Original Retina with RGB, b) A grey scale image of Blue intensity, c) A grey scale image of Red intensity With R_{max} marked in the circle (1 pixel), d) A grey scale image of R+G intensity with $R_{max} + G_{max}$ marked in the circle (2 pixels).

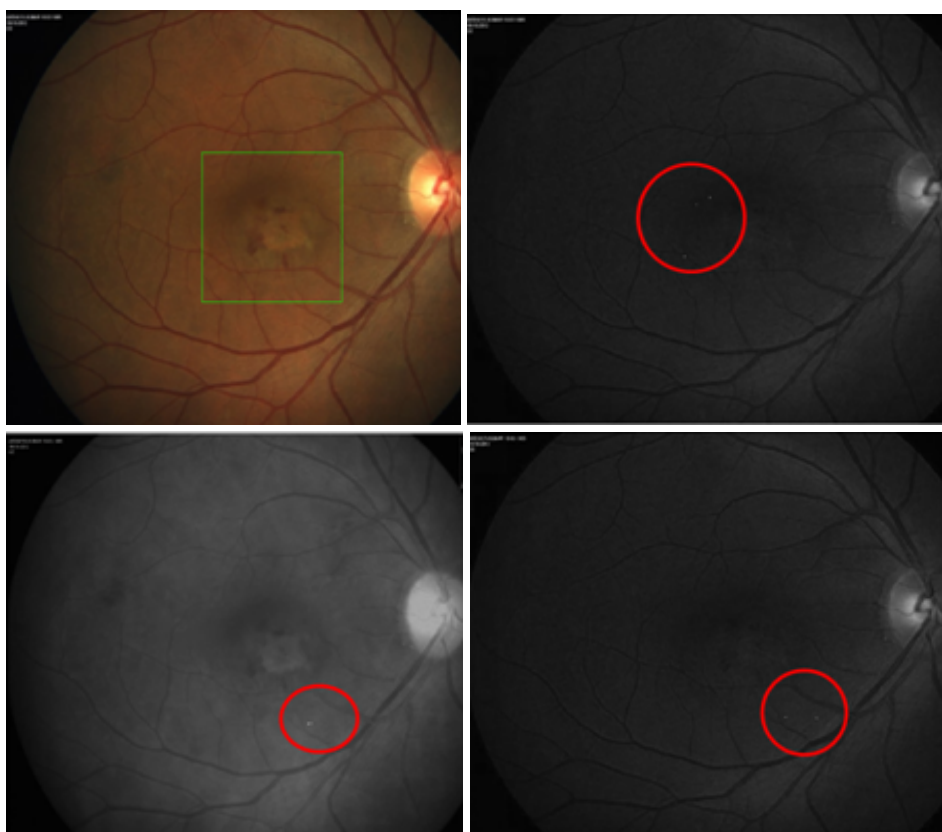


Figure 6: A Stargadt's Disease image of right eye showing all three methods and the number of pixels found a) Original Retina with RGB, b) A grey scale image of Blue intensity with, c) A grey scale image of Red intensity with R_{max} marked in the circle (5 pixels), d) A grey scale image of R+G intensity with $R_{max} + G_{max}$ marked in the circle (4 pixels).

public domain images and retinal clinic images at fovea were found to be 1.7: 1.4: 1 and 1.1: 1.1: 1 respectively alternatively for the entire retina it was found to be 2.1: 2: 1 and 1.5: 1.2: 1 respectively. As we could not completely rely on the quality of the public domain images, we had considered the images taken from the retinal clinic for further discussion on the reflectance and RGB ratios. The pixel intensities of red and green at fovea were 2.4 times and 1.6 times that of blue respectively. For the entire retina, the red and green pixel intensities reduced to 2 and 1.4 times than that of blue accordingly. The reflectivity of red and green at fovea were 1.1 times as that of blue. For the entire retina, the reflectivity increased to 1.5 and 1.2 times as that of blue. The mean (denoted by μ) values for red, green and blue reflectivity was found to be 0.88, 0.79 and 0.68 respectively at fovea. For the entire retina, it was found to be 0.47, 0.31 and

0.25 respectively. A paired t-test was performed between the red, green and blue reflectivity at fovea and the entire retina which revealed that there is a statistically significant difference with $p=0.00$ as shown in Table 2 and Figure 7. This indicated that the mean reflectivity for RGB was reduced significantly for the entire retina. This decrease is due to the higher density of rods in periphery compared to the central retina. Hence the reduced response ratio and the reflectivity can be attributed to the presence of rods. Rods play an important role in absorption and reflection of white light, as rod's peak sensitivity is at 498 nm, which is at blue end of the visible spectrum. Hence the role of rods, acting as "REGULATORS" is more, than the cones in color perception. The mean values of Reflectivity for Red & Green, Red & Blue and Green & Blue at Fovea and entire retina were compared using a paired t-test. It revealed a statistically

Table 1: RGB ratios and reflectivity ratios of normal retinal image.

	RGB Ratio		Reflectivity Ratio	
	Public domain images	Retina clinic images	Public domain images	Retina clinic images
Fovea	9 : 3 : 1	2.4 : 1.6 : 1	1.7:1.4 : 1	1.1:1.1 : 1
Entire Retina	4: 2 : 1	2 : 1.4 : 1	2.1 : 2: 1	1.5:1.2: 1

Table 2: Comparison of mean values for Reflectivity between Red, Green and Blue at Fovea and entire retina.

	μ Reflectivity At Fovea	μ Reflectivity For Entire Retina	t-test – p value
Red Reflectivity	0.88	0.47	0.00
Green Reflectivity	0.79	0.31	0.00
Blue Reflectivity	0.68	0.25	0.00

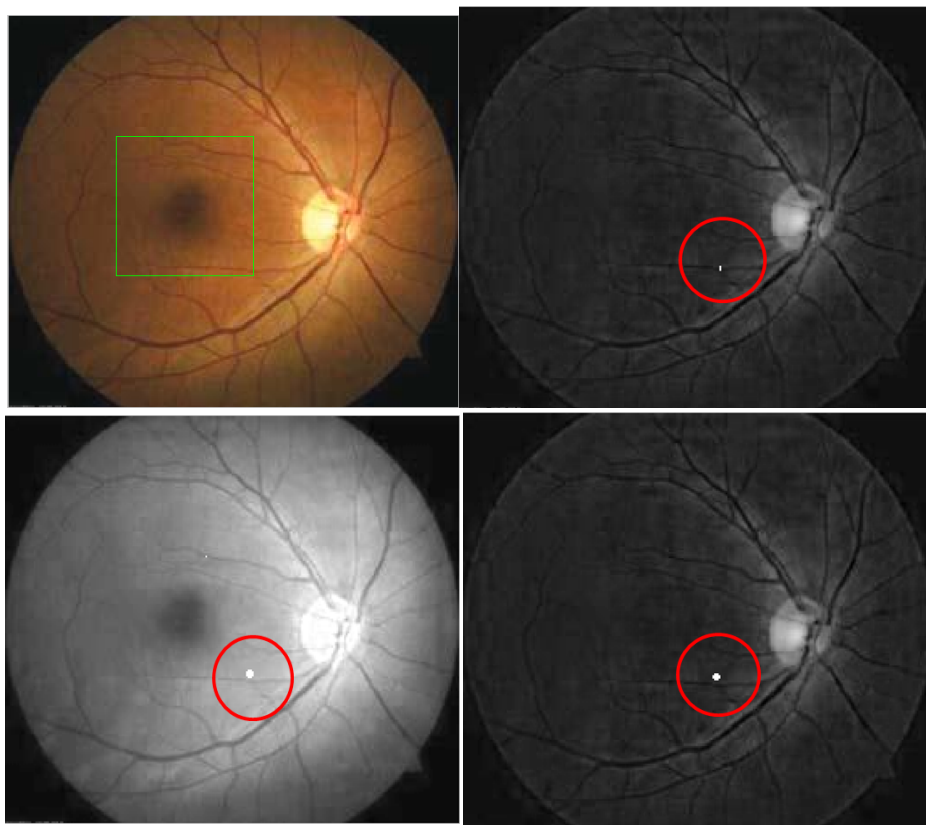


Figure 7: A Dengue retinal image showing all three methods after median filtering and the number of pixels found a) Original Retina with RGB, b) A grey scale image of Blue intensity with, c) A grey scale image of Red intensity with R_{max} marked in the circle (12 pixels), d) A grey scale image of R+G intensity with $R_{max} + G_{max}$ marked in the circle (12 pixels).

significant increase in reflectivity with $p=0.00$ for red which was more than green and blue. When compared for Green & Blue, it exhibited that green reflectivity was statistically significant when compared to blue with $p=0.01$ as shown in Table 3. This proves that the overall blue reflectivity is less as compared to red and green at both fovea and the entire retina. As the other eye of the PRL patients were normal, the age and vision was also compared with reflectivity of RGB. Pearson's correlation tests revealed a positive correlation between age and green and blue reflectivity both for the fovea and the entire retina. But Red Reflectivity for the entire retina revealed a negative correlation whereas Red Reflectivity for the fovea revealed no correlation. However for all the tests there were no statistical significance as p value was found to be more than 0.05 and is represented in Table 4. Similarly R max, R+G max and B min showed a negative correlation with age and also was not statistical significant

(Figure 8). Visual acuity measurements in Log MAR values were also compared with R max, R+G max and B min, which revealed no correlation, a positive and a negative correlation respectively along with nil statistical significance with $p>0.05$ and as given in Table 5. For PRL retinal images, B min method matched the location in 88% of cases, whereas R max and R + G max matched in all 100% cases. As our main aim was to match the location in finding out the PRL and in this work it is had matched in more than 88% of cases, all the three methods can be executed in finding out a PRL. But since the R max and R+G max can be seen in the optic disc area too, B min is a better method for ascertaining PRL's location. In the micro perimeter also, maximal decibel sensitivity is correlated with maximum retinal sensitivity location. Similarly as is proved in this work, B min can be considered as the corresponding maximal retinal sensitivity area as it is simple, fast and an effective method. The

Table 3: Comparison of mean values for Reflectivity between Red & Green, Red & Blue and Green & Blue at Fovea and the entire retina.

	Red & Green			Red & Blue			Green & Blue		
	μR	μG	p	μR	μG	p	μR	μG	p
Entire Retina	0.47	0.31	0.00	0.47	0.25	0.00	0.31	0.25	0.00
Fovea	0.88	0.79	0.00	0.88	0.68	0.00	0.79	0.68	0.01

Table 4: Correlation of Age and reflectivity at fovea and entire retina.

	Pearson's Correlation	p value
Red Reflectivity at Fovea	No	0.87
Green Reflectivity at Fovea	Positive Correlation	0.27
Blue Reflectivity at Fovea	Positive Correlation	0.11
Red Reflectivity for Entire Retina	Negative Correlation	0.38
Green Reflectivity for Entire Retina	Positive Correlation	0.20
Blue Reflectivity for Entire Retina	Positive Correlation	0.11

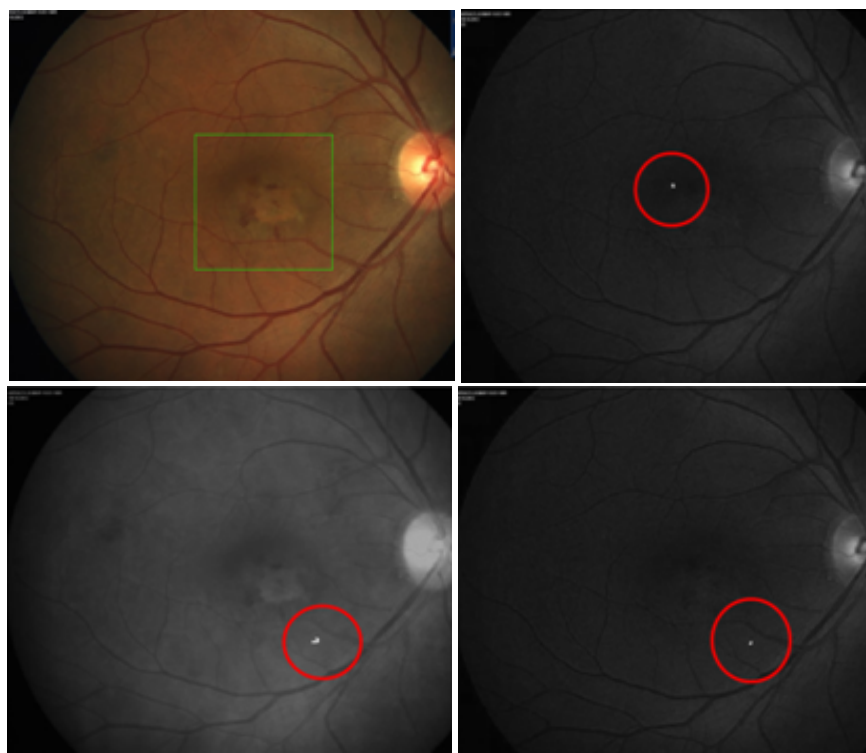


Figure 8: An image of Stargardt's Disease right eye showing all three methods and the number of pixels found after median filtering a) Original Retina with RGB. b) A grey scale image of Blue intensity c) A grey scale image of Red intensity With R_{max} marked in the circle (46 pixels) d) A grey scale image of R+G intensity with $R_{max} + G_{max}$ marked in the circle (14 pixel).

Table 5: Correlation of Age & Log MAR with R_{max} , $R+G_{max}$ and B_{min} .

	Age			Log MAR		
	R_{max}	$R+G_{max}$	B_{min}	R_{max}	$R+G_{max}$	B_{min}
Pearson's Correlation	Negative	Negative	Negative	No Correlation	Positive	Negative
p value	0.34	0.67	0.38	0.97	0.07	0.77



Figure 9: A picture of Fovea showing Blue Min area.

main limitation of this study is to correlate the identified PRL position with clinical assessment. Although this study is one of the novel methods in finding a PRL, this needs to be further investigated with prospective studies correlating clinically (Figure 9).

Conclusion

In this work, it is clearly evident that B_{min} corresponds to maximal retinal sensitivity in normal retinal images. This method further proved B_{min} matched the PRL locations in 88% of images. Hence analyzing Blue light reflectivity for patients with eccentric fixation in the retinal images is a good alternative to SLO and microperimetry.

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