Enhancement of Colour Fundus Images by using Single and Multi-Scale Retinex

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Abstract—**Lighting and image acquisition is main source that affect the image quality. Details of images are lost due improper acquisition of image modalities. There has been a renaissance of interest in the Retinex computation in the past decades, especially in its use for image enhancement. In this paper, we processed retinal colour images which suffered from varying-low contrast and shadows; images were processed through the single scale and multi-scales Retinex with gamma correction or a contrast adjustment factor to enhance, remove the shadows. The newly developed image enhancement technique gave better results with removal of the shadows and provided good contrast ratio with good improved noise level also. In this research work, 16 images were analysed with the proposed image enhancement technique. It gave better enhanced images and with more information as compared to their original images with improved 3db noise level. This result in improvement in the contrast leads to an analysis more features in the retinal colour images and especially for the analysis eye related disease and reduce invasive method such as Fundus Fluorescein angiogram (FFA) which takes injecting contrast agent.**

Index Terms— **PSNR Improvement, SS Retinex, MS Retinex, Retinal Fundus Image.**

I. INTRODUCTION

More useful information is provided by colour images for visual perception than is provided with grey scale images. The basic need of proper visualization of colour images is an enhancement of the colour image. Poor illumination conditions result in images appearing darker or having a low contrast. Enhancement of these images containing low contrast is a necessity[1]. A study has been carried out on the human vision system. Edwin land [2] initially developed the Retinex image enhancement technique in 1971. He introduced a colour theory that was developed based on colour constancy that has been in turn based on the theory of image enhancement techniques. The brain (cortex) and the retina play vital roles in the system of human vision (brain). The Retinex is a combination of the cortex (brain) and the retina. Light is detected by the retina of the eye which alters this data into an electrical signal. This signal then makes its way into the brain by way of the optic nerve. As shown in Fig 1, the process of the human vision system is carried out by the visual cortex[3].

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It has the huge undertaking of deciphering the visual world and creating for us a colourful perception of the vision. The image enhancement method presented in this paper was developed to enhance the images containing shadows and suffering from low contrast. It was created on the basis of the Retinex single and multiple scales with the gamma correction factor.

Retinex: The term "Retinex" is a combination of the term "Retina" with the term "Cortex". Eye and Brain are interconnecting source for vision processing. Colour perception is based on the human vision system. The human vision process guarantees that what the human perceives as the colour of certain objects stays relatively unchanged under different conditions of illumination. In this way, humans are able to identify objects[1]. According to physics when a red light is applied on a green page, it is not like when white light (e.g. sunlight) is applied on the same green page. However, this is not what happens in reality as the human vision tries to see the same colour no matter what colour light is applied. The Retinex effect is a physical illusion effect [1]. Traditional image enhancement algorithms, such as image sharpening[4], non-linear[5] transformation, linear, etc. can only be used to enhance a particular kind of image feature, such as for enhancing the edges of the image [6]. However, Retinex is applicable in the dynamic range compression, for edge enhancement and to achieve balance in colour constancy. Because of this, it is able to perform in various kinds of images which have been adaptively enhanced. The Retinex algorithm has been used extensively because of its many suitable properties. Among the various available Retinex-core algorithms, the most representative and most mature Retinex algorithms are the single and Multiple scale Retinex [7]. An assumption with the Retinex algorithm is that the perceived reflectance is dependent upon the relative measure of lightness[3]. This is known as the lightness sensation. This is in correlation to objects' reflectance. The principle of the Single-Scale Retinex, SSR, and algorithm is based on the Edwin Land [2] proposed theory where a given image S (x, y) is decomposed into two kinds of images. One is a reflective object image R (x, y) and the other is an incident image L (x, y).This is seen in the following schematic diagram., The Retinex intensity image is the product of the reflectance and the illumination at some specific wavelength since it does possess some wavelength[8]. This is seen in Equation 1.

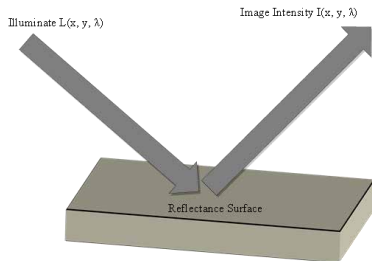$$I(x,y) = l(x,y) * R(x,y) \quad\quad (1)$$

Fig. 1. Retinex Model

Retinex Basic Model: Retinex algorithm is proposed for analysis concept of human vision system (HVS). HVS contained three components are known as three retinal cortical components and each components are independent according frequency range (Low, middle and higher frequency range). Retinex algorithm is used to determine lightness effect of each component [2]. Retinex is one of useful algorithm to compute the lightness of each RGB channel of colour image. Retinex algorithm is modeled by McCann for purpose to compute the illumination effect on every pixel of image [9]. They[1] defined the operation of Retinex algorithm is based on the ratio-product-reset and average operation and average operation model [8] are also shown below.
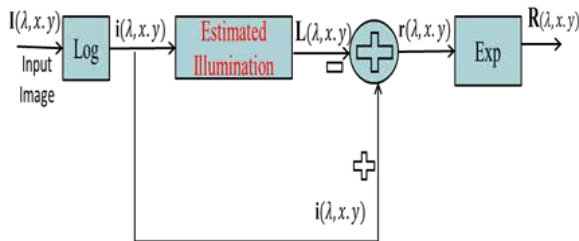

Fig. 2. Retinex General Model

Above algorithm contains on the four stages and each stage is defined below [1] .

Logarithmic Formation: The image is convert into the logarithmic form from linear formation in order to make simplest calculation of the pixels. Logarithmic conversion offers the advantage of numerical conversion from multiplication to addition and from division to subtraction.

Ratio and Product Operation: The Ratio and Product operation is used to accumulating and comparing the results for formation of new revision of a newer product of image pixels in each process of pixel comparison.

Reset and Average Operation: Reset operation is used to reset the pixel values to maintain normalisation of contrast. Average gave the final output image after user defined cycles (iteration) and that output image is known as normalised image.

Normalised Image: Finally steps give the normalised results after process all image according to ratio-product-reset and average operation.

Single Scale Retinex: SSR is one suitable method for normalised the grey scale images. Mathematically model of SSR is given in Equation 2.

$$R(x,y) = logI(x,y) - [logM(x,y) * logI(x,y)] \, [1] \quad (2)$$

R(x,y) and I(x,y) are Retinex input and output image. Input image is convolved with filter F(x,y) to give estimated illuminated image [6].

$$\mathbf{F(x,y,c) = k * Fn(x,y)[6]} \quad\quad (3)$$

$$\mathbf{F(x,y,c) =}$$
$$\mathbf{e^{\frac{(x^2+y^2)}{c^2}}} \, [6] \quad\quad (4)$$

K will be represented as
$$\iint \mathbf{F(x,y,c)}dxdy = 1 \; [6] \quad\quad (5)$$

Where the x and y are the spatial co-ordinates and c is Gaussian function constant, which is used to determine the scale of the Retinex algorithm. The operation model of the single scale Retinex is shown in Fig 3. The single scale Retinex increase the information of the uneven illumination but its output image suffers from the washout. Consider the below images output, which give the more information as compared to the original images but it suffer from the washout.
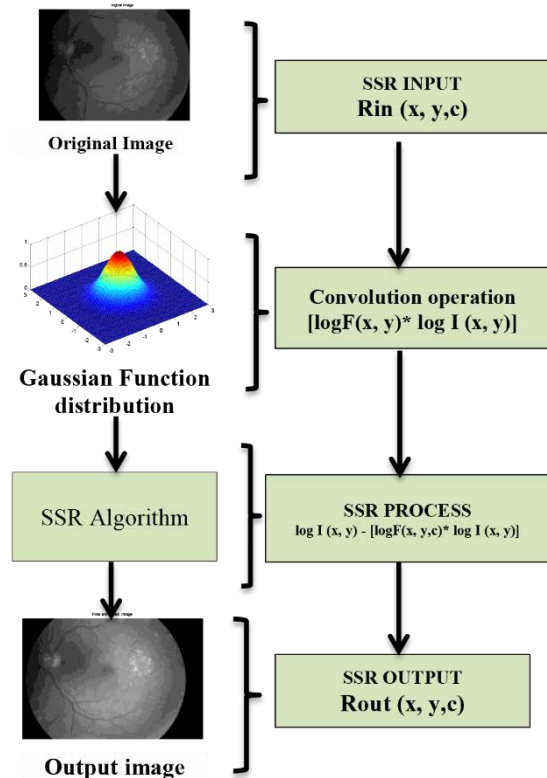

Fig. 3. SSR Algorithm

Multi Scale Retinex: Colour images contained RGB components and Retinex multi scale algorithm is used for colour images. The process of MS Retinex algorithm is depending upon the output of SS Retinex algorithm. The multi scale Retinex solve the problem of the irregular illumination in the image will be produced by the single scale Retinex because use uniform scale in the image. Multi scale Retinex has following important goals. The MS The Fig 4 is shown the multi Scale Retinex Model to process the colour image.

1. Color constancy in the image.
2. Suitable dynamic range of image.
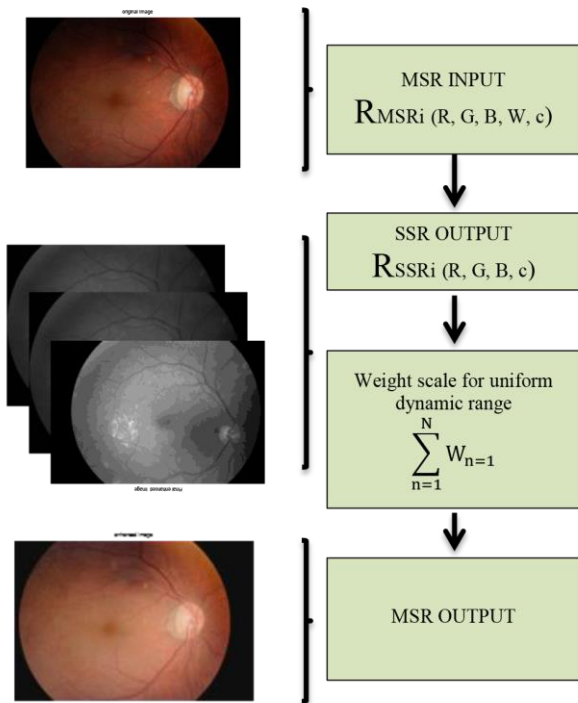3. Colour enhancement of the image.

Fig. 4.   Single Scale Retinex Model

MS Retinex is the convolution sum of the several SS Retinex. Mathematically multi scale Retinex defines in below equation.

$$R_{MSRi(x,y,w,c)} = \sum_{n=1}^{N} W * SSRni(x,y,c) \; [10] \tag{6}$$

If we processed the RGB image in the multi scale Retinex the equation can be write.

$$R_{Mi(R,G.B,W,C)} = \sum_{n=1}^{N} W_n * SSR_{(R,G,B,C)} \; [10] \tag{7}$$

Where the $R_{MSRi(x,y,w,c)}$ is the multi scale result channel with W= (w1, w2…………wn) nth weight scale of single scale Retinex with its Gaussian function. Similarly $R_{Mi(R,G.B,W,C)}$ is the multi scale result of every channel red, green, and blue of RGB input with weight scale of red, green, blue channel of single scale Retinex[10].
There are many Retinex model, the below Table 1. show comparison of the image enhancement technique[11] with other image enhancement techniques[12].

TABLE I. COMPARISON TABLE OF IMAGE ENHANCEMENT TECHNIQUE

Technique	Advantages	Disadvantages
Contrast Stretching [13]	Good visual representation of image.	Lost of information due to saturation levels and clippings.
Histogram Equalization [13]	Produce best contrast result with uniform histogram.	Preserve the brightness in the image. It can't suitable to adjust the local information of the image.
Contrast Limited Adaptive HE [14]	Enhanced the local contrast.	Produce noise and artifacts and edges lost details of image.
Single Scale Retinex [3]	Give more details with suitable dynamic range compression.	Details are lost due wash out appearance.
Multi Scale Retinex [3]	Give more Details of image as compared to SSR	Tiny details are lost due wash out appearance.

II. APPROACH

In this research paper the image contains shadow and any artifacts are processed through the multi-scale Retinex with contrast adjust factor to give proper illuminated and best contrast images, which give more information as compared with original image. The contrast adjust factor is used because sometime image can be over enhanced so adjust factor is known as contrast adjust factor or gamma correction factor avoided the image from over enhancement. The main purpose of this research to enhance the bio-medical images like colour fundus images and acnes (skin images) to remove the shadow and artifacts in the images. The purpose algorithm gave good results on natural images which contains shadow. In this research fundus images and natural images are processed. The model of the proposed algorithm is shown below Fig 5.
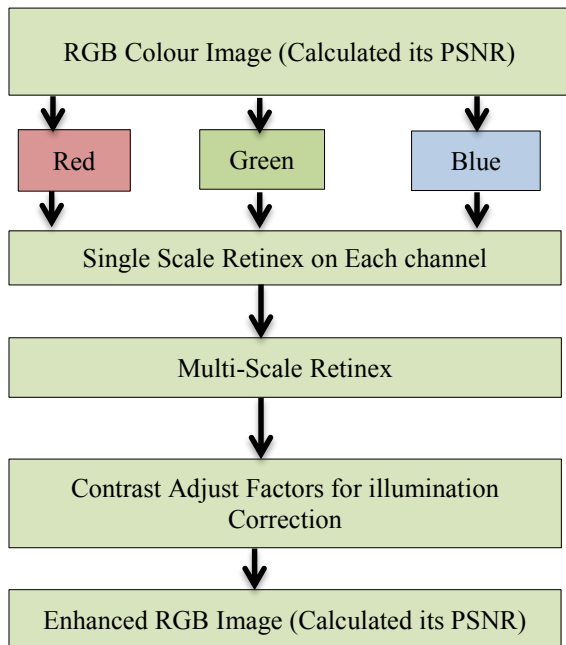
Fig. 5. Proposed Algorithms

The color images are processed through above approach in Fig 5. The SS Retinex was used to normalize the contrast of each RGB channel, and then finally to normalize the RGB image, it was processed with the multi scale Retinex for further enhancement. Moreover, the contrast adjustment factor was used to avoid obtaining an over enhanced image. Gamma correction was used as the contrast adjustment factor for the illumination correction in the image. It adjusted the illumination in the image and it assigned values from 1 to infinity. In this algorithm, the authors selected gamma as any value between 0 and infinity because variation of illumination in fundus image lost the details and illumination can make proper by setting gamma values. If gamma factor is less than 1 then images pixels value moves to lower level and gave darker effect. If gamma factor is higher than 1 then brightness is occurred in the image. For suitable selection of gamma factor give proper illumination effect in the image. Therefore the three values 01, 1.5 and 2.5 of gamma factors are selected for the best illumination in the image. The value of 1.5 gave the best result in all of the proposed images

III. RESULTS AND ANALYSIS

The proposed image enhancement approach is based on the MS Retinex along with contrast adjust factor. The 16 colour fundus images are analyzed by using proposed image enhancement approach. These images were taken from 35-Fundus image database and captured by using fundus camera Kowa 7 and it was taken for experimental work to analysis colour fundus image for diagnosis of eye disease [15]. Consider 9 fundus colour images in the below Fig 6 as example.
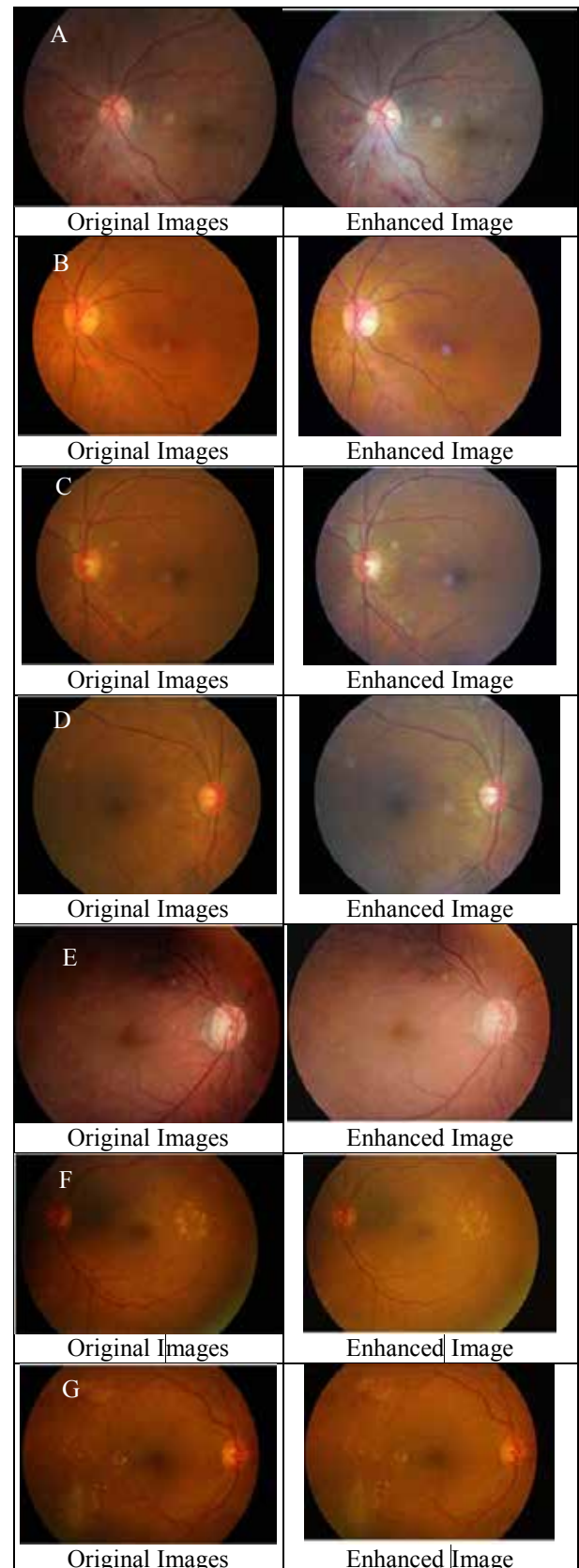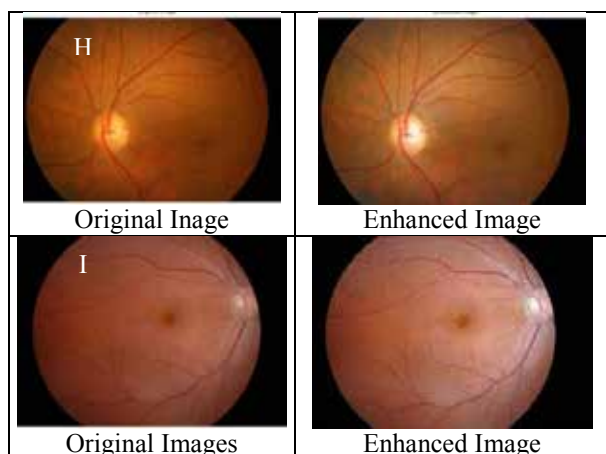
Fig. 6. Multi Scale Retinex for Fundus Images

Considering Fig 6, the retinal fundus image was processed for enhancement by using the proposed image enhancement technique. In the image set A in Figure 6, the original image contains dark shadows due to which pathologies in the retinal fundus image could not be analyzed clearly. The enhanced image is better as compared to the original image and all the pathologies can be observed easily. Similarly, the entire sets of enhanced images were much better as compared to the original images, such as is seen with the image sets from B to I, these images contains allots dark shadow due to which the blood vessels cannot seen clearly but the enhanced image remove dark shadow and gave more information as compared to the original images.

Consider below Fig 7 based on the PSNR analysed of green band image of both methods because green band image gave higher contrast usually in Retinal fundus image as compared to other two bands (PSNR is calculated according to Equation 2) in which Single scale Retinex give the PSNR improvement 1.5dB and Multi scale Retinex gave PSNR improvement of 2.7 dB , it indicates that Retinex algorithm can be used for normalised the varied contrast and it will be give better result in pre-processing steps for further and gave high contrast improvement factor as compared to invasive eye related modality.

$$PSNR = 20 \, log_{10}(\frac{255}{\sigma}) \qquad (8)$$

In the Equation 8, the σ is the standard deviation of the image intensities and 255 is considered as peak intensity of a digital image.
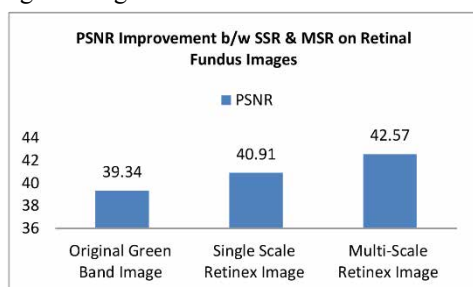

Fig. 7. PSNR based Analysed

IV. CONCLUSION

Analyzing the colour images which suffer from varying contrast, low contrast and contains brighter or darker type of shadow is difficult. Especially the blood vessels of the retinal fundus are suffering varied and low contrast against its surrounding background. It make difficult to determine the retinal vasculature accurately.

In this work, developed enhancement method called Multi scale Retinex along with contrast adjust factor. It is used to enhance the colour images and remove the shadow from the images. This enhancement techniques for bio-medical like acnes images and fundus images because these types images suffer from low contrasts and artefacts so it need to enhance to remove artefacts and give uniform contrast for analysis the image.

In this research work 16 images are analysed and proposed image enhancement technique give better enhanced images with more information as compared to their original images with reduce noise level of apprx:1.5db (SSR) and 3db(MSR). This result in improvement in the contrast leads to analysis the more features of the colour images and especially analysis the bio-medical images.

REFERENCES

[1] J. M. Brian Funt Florian Ciurea "Retinex in MATLAB™," *Journal of Electronic Imaging,* pp. 48–57, 2004.

[2] E. H. Land and J. J. McCann, "Lightness and Retinex Theory," J. Opt. Soc. Am., vol. 61, pp. 1-11, 1971.

[3] R. Zia-ur, J. D. J., and W. G. A., "Multi-Scale Retinex for Color Image Enhancement," NASA Langley Technical Report Server1996.

[4] M. Ogata, T. Tsuchiya, T. Kubozono, and K. Ueda, "Dynamic range compression based on illumination compensation," *IEEE Trans. on Consum. Electron.,* vol. 47, pp. 548-558, 2001.

[5] T. Okuno and T. Nishitani, "Efficient multi-scale retinex algorithm using multi-rate image processing," presented at the Proceedings of the 16th IEEE international conference on Image processing, Cairo, Egypt, 2009.

[6] Z.-u. Rahman, D. J. Jobson, and G. A. Woodell, "Investigating the relationship between image enhancement and image compression in the context of the multi-scale retinex," *J. Vis. Comun. Image Represent.,* vol. 22, pp. 237-250, 2011.

[7] S. G. Vázquez, N. Barreira, M. G. Penedo, M. Saez, and A. Pose-Reino, "Using Retinex Image Enhancement to Improve the Artery/Vein Classification in Retinal Images," in *Image Analysis and Recognition.* vol. 6112, A. Campilho and M. Kamel, Eds., ed: Springer Berlin Heidelberg, 2010, pp. 50-59.

[8] H. A. Nugroho, "Non-Invasive Image Enhancement of Colour Retinal Fundus Image for Computerised Diabetic Retinopathy Monitoring and Grading System," *In Phd Thesis Electrical and Electronics Engineering Programme Bander Seri Iskandar , Malaysia , Universiti Teknologi PETRONAS,* 2012.

[9] Y. Cheng, Y. Wang, and Y. Hu, "Image enhancement algorithm based on Retinex for small-bore steel tube butt weld's X-ray imaging," *WSEAS Trans. Math.,* vol. 8, pp. 279-288, 2009.

[10] Y. Liu, Y. Su, Y. Zhu, and Z. Yuan, "A multi-scale retinex algorithm for image enhancement," 2005, pp. 131-133.

[11] K.-C. Chen, "Color image enhancement," presented at the Proceedings of the 30th annual Southeast regional conference, Raleigh, North Carolina, 1992.

[12] J. Xia, K. Panetta, and S. Agaian, "Comparative study of color image enhancement techniques," pp. 806316-806316, 2011.

[13] M. S. Miri and A. Mahloojifar, "A comparison study to evaluate retinal image enhancement techniques," in *Signal and Image*

Processing Applications (ICSIPA), 2009 IEEE International Conference on, 2009, pp. 90-94.

[14] H. B. Vinay Kumar, ECE Department, NIT, Kurukshetra, Harayana, India, "Performance Evaluation of Contrast Enhancement Techniques for Digital Images," *IJCST,* 2011.

[15] A. F. M. Hani, T. Ahmed Soomro, H. Nugroho, and H. A. Nugroho, "Enhancement of colour fundus image and FFA image using RETICA," in *Biomedical Engineering and Sciences (IECBES), 2012 IEEE EMBS Conference on*, 2012, pp. 831-836.