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Adequate Pre-Processing Method to Estimate Neovascularization in Diabetic Retinopathy

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Abstract: Fundus images are mainly used for screening the diabetic retinopathy, an eye disease which causes progressive damage to the retina due to the changes in hyperglycemia levels of the person. Neovascularization is the worst case of retinal abnormality of proliferative diabetic retinopathy where abnormal growth of new blood vessels grows in retinal part and the optic disc region of the eye due to the pressure built in the blood vessels. To analyze these blood vessels here the pre-processing method state initially, the neovascularization fundus image is split into R, G, B planes and hence each planes gets converted into gray scale image. Neovascularization blood vessels are twisted and thin nature, the Green plane of the image looks clearer than the Red and Blue plane of the fundus image. Another progression has been done as normalizing the input image by means of pre-specified mean and variance which increase the contrast of the image without changing the image features. After normalization the image will be subjected to split into R, G, B planes; here too the Green plane is selected which gives the confident level in finding the abnormal growth of blood vessels. Finally, the contrast scale difference between the two green planes of the images can be analyzed using pairwise Euclidean distance and brightness differences shown using bar chart. Performance outcome shows as the scale difference in 0.111 just increases the contrast of the image by suppressing the background gives the clear view of blood vessels used to analyze the neovascularization in fundus image to screen the DR for future research.

Key words: Diabetic retinopathy, neovascularization, normalization, pairwise Euclidean distance, RGB

INTRODUCTION

In medical imaging, retinal images are used for the diabetic retinopathy. The retinal images are generally corrupted by noise in its acquisition or transmission. There are various sources to cause noise such as inherent in the use of charge coupled device, other external effects such as space radiation like cosmic rays can have negative effects in the accomplished data. The pre-processing technique deals with various initial issues in intensity variations in images, noises in images, blurred image, etc. The retinal image quality must be improved for the detection of features and abnormalities presented in the eye. Upon that neovascularization is the growth of twisted abnormal blood vessels in the retinal region due to diabetic retinopathy need to be analysed to keep patients living. And here the sufficient pre-processing technique to evaluate the neovascularization in diabetic retinopathy fundus image has been proposed using image processing procedure.

Diabetic Retinopathy (DR), the most common diabetic eye disease, occurs when blood vessels in the retina change due to prolonged hyperglycaemia, i.e., diabetes mellitus. Presently, WHO states as approximately 197 million people worldwide have diabetes mellitus. India sadly is emerging as a world leader in diabetes prevalence and currently has 40.9 million patients (Suma and Kavitha, 2013). Diabetes milletus lead to affect eyes, kidneys, digestion and skin (Suma and Kavitha, 2013). Initially, eyes are affected and the people do not notice changes in their vision affected by the disease in early stages (Suma and Kavitha, 2013). But as it progresses, diabetic retinopathy usually causes vision loss that in many cases which can not be reversed. Fundus photography is widely used for large scale detection of diabetic retinopathy, glaucoma and age-related macular degeneration (Suma and Kavitha, 2013). Fundus photography is the creation of a photograph of the interior surface of the eye including the retina, blood vessels, macula, fovea and optic disc.

The abnormalities that occur due to Diabetes mellitus are Non-Proliferative Diabetic Retinopathy (NPDR) and Proliferative Diabetic Retinopathy (PDR) (Suma and Kavitha, 2013). Non-Proliferative Diabetic Retinopathy (NPDR) damages the blood vessels in retina begins to leak extra fluid and small amounts of blood into the eye

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which enclose Microaneurysms, Haemorrhages, Exudates, Macular edema, Macular ischemia (Suma and Kavitha, 2013). Proliferative Diabetic Retinopathy (PDR) encloses Vitreous haemorrhage, Traction retinal detachment, neovascular glaucoma, neovascularization mainly occurs when many of the blood vessels in the retina close, preventing enough blood flow (Suma and Kavitha, 2013). In an attempt to supply blood to the area where the original vessels closed, the retina responds by growing new blood vessels. Hence, it results in development of abnormal growth of blood vessels in patient's retinal part of eye (Suma and Kavitha, 2013) is called neovascularization.

Literature review: For several years, a lot of studies have been done on image analysis and image understanding where medical images play a vital role in it. Hence, DR is serious sight issue in these days there are many research work are carrying out to resolve the same. In that very less research work has been proposed out to detect the abnormal growth of blood vessels in neovascularization under diabetic retinopathy (Suma and Kavitha, 2013). And many researches done for developing an online system for analysis of eye diseases, detecting anatomical structure of fundus image as retina, blood vessels, optic disc for surgical point of view showing abnormalities such as hemorrhages and exudates merely (Suma and Kavitha, 2013). Where the neovascularization is not analyzed by researchers in lot because of the intensity resemblance, i.e., both normal blood vessels and abnormal blood vessels seems to be the same and differs only in their appearance.

Salem and Nandi (2007) proposed a novel pre-processing method for color fundus images with the contribution of the red plane too. Generally, for fundus image analysis many discussions made through only the green plane but in the study (Salem and Nandi, 2007) the method utilizes the intensity information from both Red and Green planes. The histogram matching is used to modify the histogram of the Green plane by using the histogram of the Red plane which corrects non-uniform illumination in color fundus images. Results show that the use of HM image gives better performance than using the Green plane image as specificity of 90%, in case of abnormal images with the sensitivity of 76% in normal images (Salem and Nandi, 2007).

The artifacts of fundus image have been discussed in study, where Narasimha-Iyer *et al.* (2007) states that non-uniform illumination in retinal image is corrected using the Iterative Robust Homomorphic Surface Fitting algorithm (Narasimha-Iyer *et al.*, 2007). The algorithm estimates the illumination and reflectance components from the fundus image by homomorphic filtering and robust surface fitting and extracts the retinal features such as the blood vessels, optic disk and fovea and lesions which have different reflectance properties compared to the normal retinal background (Narasimha-Iyer *et al.*, 2007). The study (Liang *et al.*, 2008) which also clearly explains the blood vessels are always darker than their surroundings by its gray-level variations. Post-processing step fills pixel gaps in detected blood vessels and removes falsely-detected isolated vessel pixels (Liang *et al.*, 2008). The post processing results the bright retinal structures are removed (i.e., optic disc, exudates or reflection artifacts), the darker structures remaining after the opening operation become enhanced (i.e., blood vessels, fovea and possible existence of Microaneurysms or haemorrhages) (Liang *et al.*, 2008).

Goatman *et al.* (2011) proposed the similar research in Neovascularization concentrates only in optic disc of the fundus image. The study states as the green color plane was used for analysis of neovascularization since it shows the best contrast between the vessels and the background retina (Goatman *et al.*, 2011). Abdallah *et al.* (2013) and Aquino *et al.* (2010) supposed as the situation of retinal image denoising, the noise type and stage of the noise generated by digital cameras are unrevealed hence the information about the sensor and circuitry of a digital camera are not enough. And the most of algorithms presume that the noise is additive and independent of the RGB image data and is too a Gaussian sample, etc. Therefore, any approaches cannot effectively recover the correct process from the noisy acquired interpretation due to its artifacts existing in the fundus image.

Artifacts in fundus image: Due to imperfections in the captured image like non-uniform ink intensity and other several issues, the input image may exhibit distorted levels of variation in color that should be solve in pre-processing level. There are several artifacts in screening the disease through fundus image are as follows:

- Due to the presence of charge coupled device in Fundus camera there might be presence of some noise as like as in digital images
- The electrical impulses of photoreceptors travel the image to brain. So, the optical disc looks brighter than the other retinal regions. The effort should also concentrates in optic disc and due to the over brightness of optic disc, neovascularization in optic disc cannot be viewed clearly

- The overall retinal region is about 150 mm but through the fundus image it is possible to view only 10 mm in diameter along with blood vessels
- There is a chance of blurred fundus image because of the iris expansion and shrinking nature

Therefore, it is desirable to develop a technique that can perform pre-processing method to evaluate the neovascularization in DR. Hence, the study explains the pre-processing step is presently an initial step for the further processing of the researches in the Fundus images.

MATERIALS AND METHODS

The developed technique makes use of major image processing methods and fundamentals. In order to perform the preprocessing in neovascularized DR image there are several methods has been handled as mentioned in study. The proposed preprocessing technique which provides the adequate procedure to analyze the new blood vessels presented in the fundus image is shown in Fig. 1.

In proposed method, using the image processing concept the neovascularized fundus image gets split into Red, Green and Blue planes. A RGB color image consists of three different color planes Red, Green and Blue and each color layer will be a gray-scale image. Upon that Red plane of an image which provides more brightness than the other two planes, Blue plane which provides more contrast than the other two planes. Hence, the Green plane looks more suitable for the research work regarding neovascularization detection.

Hence, the fundus image has been captured using charge couple device and to solve other related artifacts as mentioned in study normalization is used as main role. Normalization refers to an image processing method aimed at correcting the differences by shifting the relative brightness values up or down before assessing the number of pixels contained within the threshold limits. Doing normalization and then splitting the image into RGB planes which gives added contrast than the original input image splitting process which leads to find blood vessels clearly. The proposed pre-processing algorithm consists of four major steps:

- Split the RGB planes from the neovascularized input fundus image. Extract the Green plane from the image. Calculate the Green plane grayscale image brightness
- Increase the contrast of the input fundus image by normalization with the small mean and variance values
- Split the RGB planes from the normalized fundus image. Extract the Green plane normalized image. Calculate the normalized Green plane grayscale image brightness
- Finally, calculate the contrast change between the two green planes via pairwise Euclidean distance using histogram values

Implementation: Extracting the clear retinal image information is a prerequisite for diagnosing the diseases and this study explains the adequate pre-processing procedure to analyze the neovascularization in diabetic retinopathy. The research is planned to evaluate the neovascularization in both optic disc region and retinal part region of the eye. And the preprocessing research should not disturb the new blood vessels in any manner thus the proposed method gives sufficient solution for the above concern.

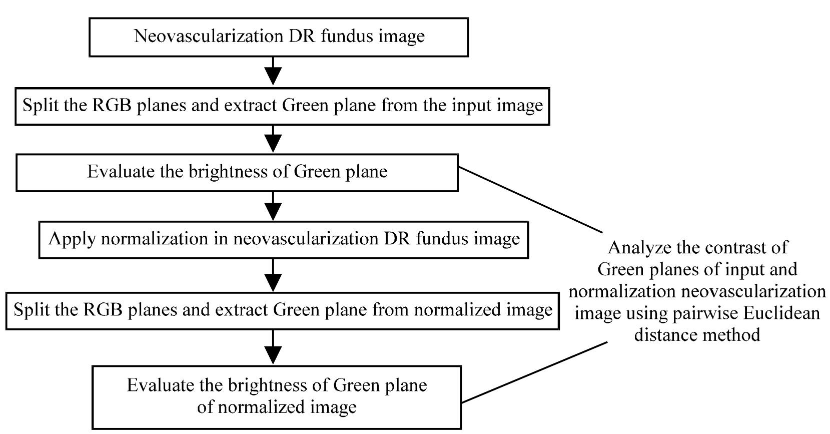

Fig. 1: Flowchart of pre-processing method

Fig. 2: Input image with neovascularization

Input data-splitting RGB planes from the input data: Neovascularization is a serious sight threatening disease of diabetes patient where the present retinal vessels get closed. Pressure builds up in the eye which leads to grow new blood vessels that block the normal flow of fluid out of the eye, cause damage to the optic nerve and the retinal region of the eye. The neovascularized input image is shown in Fig. 2. The fundus image with neovascularization has several difficulties as mentioned in study hence, the following preprocessing method provides satisfactory procedure for the same.

Firstly, the input neovascularization fundus image is subjected to split into individual Red, Green, Blue planes. The RGB retinal image shows where R, G and B represents Red, Green and Blue component of retinal image. After splitting each color the layer will become a gray scale image. Hence from the image in RGB format, the H component of each RGB pixel is obtained using the Eq. 1 as:

$$H = \begin{cases} \theta & \text{if } B \leq G \\ 360\text{-}\theta & \text{if } B > G \end{cases} \tag{1}$$

With:

$$\theta = \cos^{-1}\left\{\frac{0.5\left[(R\text{-}G)+(R\text{-}B)\right]}{\left[(R\text{-}G)^2+(R\text{-}B)(G\text{-}B)\right]^2}\right\} \tag{2}$$

The saturation component is given in Eq. 3:

$$S = 1\text{-}\frac{3}{(R+G+B)}\left[\min(R, G, B)\right] \tag{3}$$

Finally, the intensity component is given in Eq. 4:

$$I = \frac{1}{3(R+G+B)} \tag{4}$$

The way a human experiences colors and secondly noise can be easily removed in HSI color space. So, the color fundus image has split into R, G and B planes as in Fig. 3a, c and e and the corresponding histogram has also been performed in Fig. 3b, d and f to analyze the brightness as well as contrast differences in the images.

Figure 3a is the Red plane of input neovascularization fundus image which eliminates the blood vessels presents in the optic disc region and hence the extraction of Red plane is not suitable doing future researches. Figure 3e is the Blue plane of neovascularized input fundus image which has high contrast where the blood vessels can not be identified correctly. Figure 3c is the Green plane which clearly shows all the blood vessels presented in retinal and the optic disc region and hence the Green plane is chosen for the further processing. Hence, there is a necessitate to consider the small twisted abnormal blood vessels, i.e., neovascularization and the plane Green is selected as the obvious one by leaving other planes without any considerations is determined.

Normalization-splitting RGB planes from normalized neovascularized input data: Enhancement techniques have been developed to improve the quality of images. Here, normalization is performed to reduce the effects of sensor noise and grey level deformation due to artifacts presents in fundus images. Normalization researches as pre-processing for the neovascularization fundus image which researches with the pre-specified mean and variance.

Normalization concept introduce in pre-processing technique to make fine changes in color level variations. Generally, normalization technique is used for Fingerprint Pre-processing Method (Suma *et al*., 2012) which does not eliminate any ridges and valleys from the image. Rather the method which suppresses the value of background and the ridges values will never get change from its values (Suma *et et al*., 2012). Normalization method do not erase any input values just increases the contrast in small level in variations (Suma *et al*., 2012). Thus, neovascularization which involves thin blood vessels which looks very skinny in nature can get its contrast increased by means of normalization. Figure 2 is used as to convert the image into normalized image.

Let I(x, y) denote the gray value at pixel (x, y), M_i and V_i, the estimated mean and variance of sector S_i, respectively. And N_i(x, y), the normalized gray-level value at pixel (x, y). For all the pixels in sector S_i, the normalized image is defined as:

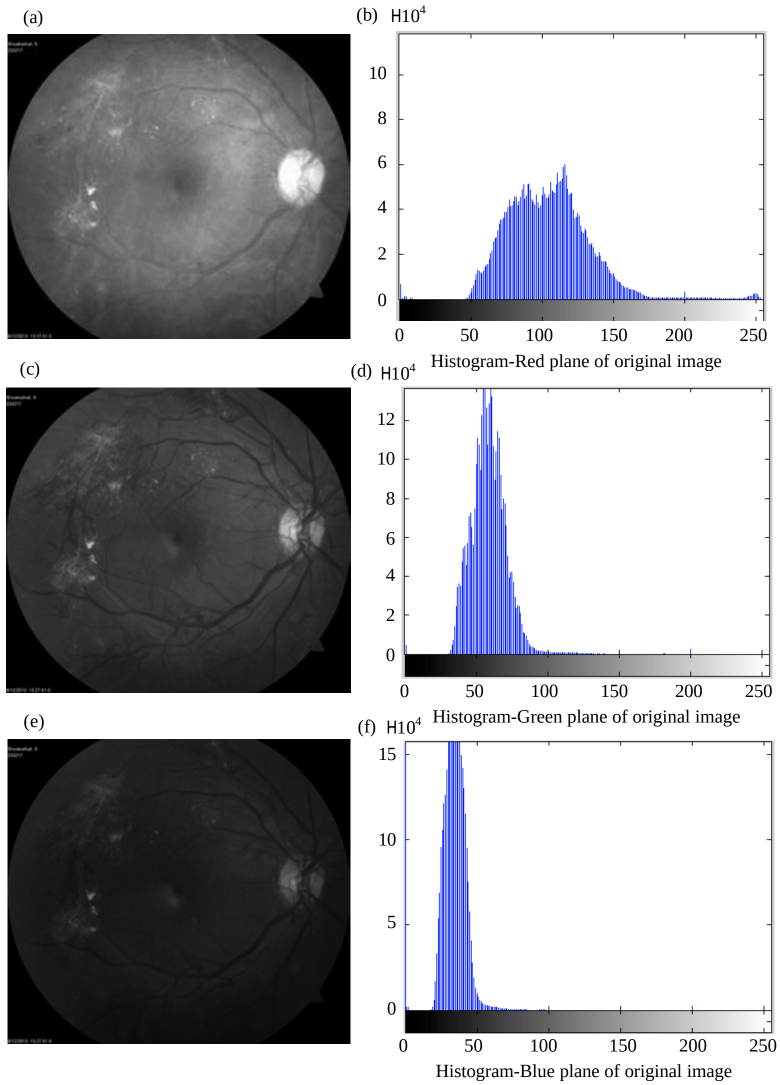

Fig. 3: Splitting the RGB planes from input neovascularization image; a) Red plane of input image; b) histogram of Red plane of input image; c) Green plane of input image; d) histogram of Green plane of input image; e) Blue plane of Input image and f) histogram of Blue plane of inpute image

$$N_i(x,y)=\begin{cases} M_0+\sqrt{\dfrac{V_0\times(I(x,y)-M_i)^2}{V_i}} & \text{if } (x,y)>M_i \\ M_0-\sqrt{\dfrac{V_0\times(I(x,y)-M_i)^2}{V_i}} & \text{otherwise} \end{cases} \quad (5)$$

where, M_0 and V_0 are the desired mean and variance values, respectively. Normalization is a pixel-wise operation which does not change the clarity of the blood vessels present in the image. Neovascularization which involves thin twisted nature blood vessels also does not get change due to normalization rather it will just suppress the background and provide blood vessels more bright full than the input image shown in Fig. 4b. The normalization of neovascularized fundus image done with desired mean of zero and a variance of one. Then, the normalized neovascularization fundus image subjected into split individual Red, Green, Blue planes and extract the Green plane as same as in study.

The R, G and B planes of normalized fundus image shows that only contrast has been increased than the original fundus image planes verified with histograms. The histogram of the Green plane (Fig. 3d) of fundus image illustrates that the intensity values lie on the right hand side of the 0-255 scale, i.e., presented within 50-100th scale. This results in the image having a low contrast shown in Fig. 3c. On the other hand, the histogram of the Normalized Neovascularization Green plane of Fundus image (Fig. 5d) shows that the range of

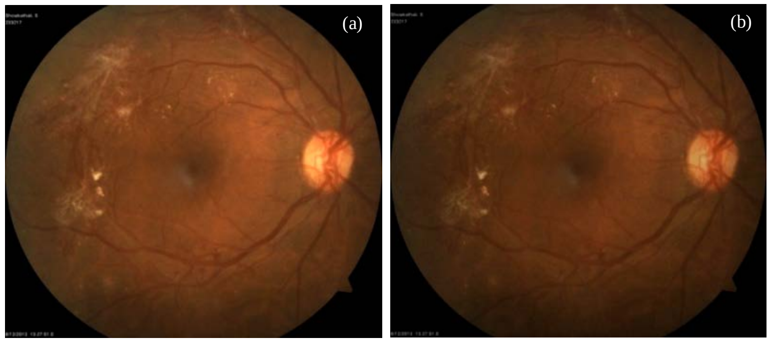

Fig. 4: a) Neovascularization input image and b) normalization of neovascularization input image

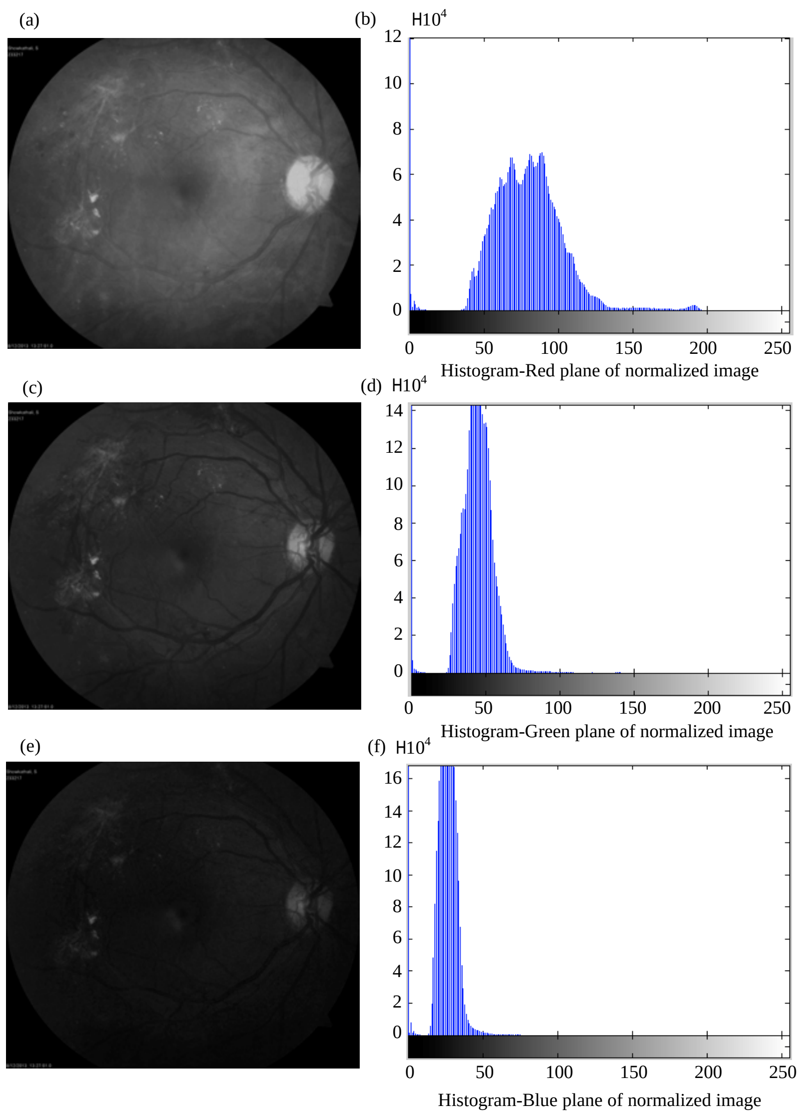

Fig. 5: Splitting the RGB planes from normalized neovascularization image; a) Red plane of normalized neovascularization fundus image; b) histogram of Red plane of normalized neovascularization fundus image; c) Green plane of normalized neovascularization fundus; d) histogram of Green plane of normalized neovascularization fundus image; e) Blue plane of normalized neovascularization fundus image and f) histogram of Blue plane of normalized neovascularization fundus image

intensity values has been adjusted in 0.11 scales explicate as contrast is increased in normalized image. Figure 5d shows a more balanced distribution between the dark and light pixels. The histograms plots in Fig. 3d and 5d shows that the normalization process does not alter the shape of the original histogram plot, only the relative position of the values along the x-axis is shifted which clarify the structure of the blood vessels and fundus image features are not changed only the background of the image get suppressed.

Then, it is stated that Fig. 5c the Green plane only shows all the blood vessels without any elimination as in Red plane or high contrast rise as in Blue plane. And the Green plane under normalization which has been evaluate as the clear image to view the neovascularized fundus image. Hence, the difference in contrast of Green planes between input and normalized image can be calculated using the Euclidean distanceof images.

Euclidean distance is an Ordinary Distance Method which evaluates the distance between two points and here the Eq. 6 used to analyze the contrast distance difference between the Green planes of the images with histogram. If $p = (p_1, p_2, ..., p_n)$ and $q = (q_1, q_2, ..., q_n)$ are two points in Euclidean n-space then the distance from p to q or from q to p is given by: Euclidean distance for two dimension image states as:

$$d(p, q)=\sqrt{(p_1-q_1)^2+(p_2-q_2)^2} \quad (6)$$

The pairwise Euclidean distance has been used to calculate the distance difference between the row and column wise observations. Thus, PED returns a matrix D containing the Euclidean distances between each pair of observations in them x-by-ndata matrix X and m-by-n data matrix Y. Here, the pairwise Euclidean distance calculates the contrast scale difference between the input Green plane image and normalized Green plane image.

RESULTS AND DISCUSSION

All the input images are subjected to the image enhancement process: a desired mean value of zero and a variance of one are used for normalization to increase the contrast. Therefore, each input image is normalized to a pre-determined level before proceeding on to the subsequent enhancement stages. Then, the normalized input image split R, G, B planes and the Green plane is extracted from the image were used for further progression. Hence, pairwise Euclidean distance researches for single and double precision used to analyze the large inputs. Table 1 shows the contrast increased difference using PED and also evaluates the brightness of input image and normalized image Green planes. The brightness reduced difference between the Green planes is shown in Fig. 6, respectively.

The performance in the contrast has been averaged as 0.111 which just increases the contrast of the image by suppressing the background gives the clear view of blood vessels shown in Table 1. Thus, the pre-processing method converse the adequate procedure for analyzing the neovascularization in fundus image and Green plane of normalized neovascularization fundus image is certain as the precise image detection measures for future researches.

Given the pre-processing method gives the adequate technique to analyze the abnormal growth of blood vessels in fundus image. Normalizing and then splitting the fundus image into R, G, B planes gives the fine solution to find the neovascularization blood vessels where the extracting the Green plane provide as the suitable image for the further processing researches. So,

Table 1: Brightness and contrast difference between input and normalized neovascularization fundus image

Neovascularized input image	Brightness of neovascularization input image			Brightness of normalized neovascularization image			Contrast scale difference between Green planes of input and normalized neovascularization images using pairwise Euclidean distance equation
	Red plane	Green plane	Blue plane	Red plane	Green plane	Blue plane	
8475 Sugumar RSUGR (98488)	103.0334	66.3465	39.3118	79.0705	50.8675	30.1930	0.1491
146816 Nainarmohamed SNAIS (98699)	90.9729	65.5518	49.0932	69.7709	50.2395	37.6712	0.0670
204418 Sundaravalli RSUNR (68770)	91.7234	75.6233	45.8244	70.4021	57.9634	35.1549	0.0809
8475 Sugumar RSUGR (98498)	98.6375	65.6878	40.1852	75.6976	50.3302	30.8680	0.1270
221035 Selvam MSELM (83185)	74.1694	60.4310	36.5427	56.8444	46.3658	27.9992	0.0884
224423 Neelamegam SNEES (85269)	67.8911	56.8567	33.4465	52.0333	43.5978	25.7330	0.1463
233217 Showkathali SSHOS (91193)	88.9520	50.2963	29.6256	68.2165	38.5345	22.7722	0.1241

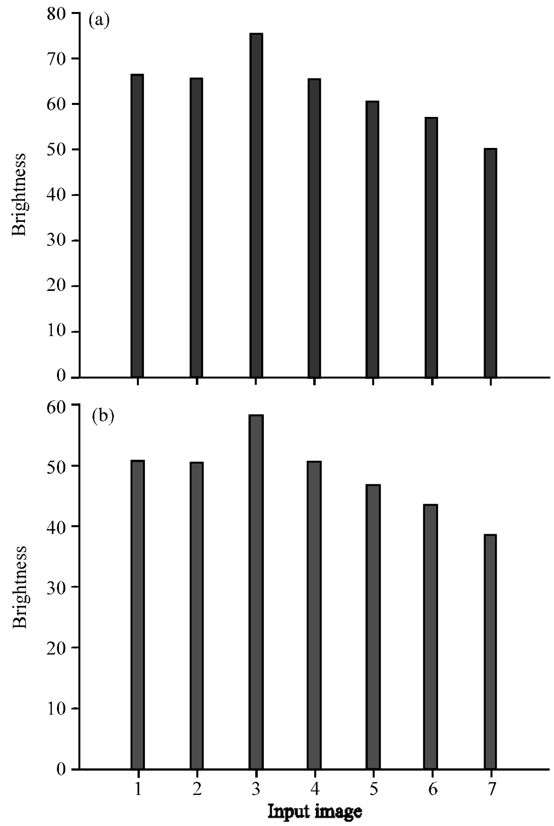

Fig. 6: Brightness chart between Green planes of; a) input image and b) normalized image

normalization concept which helps to improve the contrast level of the image which enhances the blood vessels presented in the image without making any changes in the images. Figure 5d shows that Green plane after normalization suits for detecting the neovascularization blood vessels successfully. The above pre-processing procedure researches very well with all the artifacts of fundus image and here it is explore how the Green plane from the color image plays a vital role in medical images.

CONCLUSION

Abnormal growth of blood vessels present in diabetic patients which causes serious sight threatening disease and the research work regarding in the area which provides great revolutionize in their living. The proposed method of normalizing and extracting the Green plane of the same which provides the contrast increment provides a passable way to detect the neovascularization presents in Fundus image. Neovascularization can not be detected so easily because of the artifacts and image nature. So, a Preprocessing system is essential to analyze the abnormal blood vessels presented in the fundus image of diabetic retinopathy that will be useful for professional graders.

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