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Blood Vessel Contrast Enhancement Techniques for Retinal Images

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Abstract: In today's world, Digital image processing has left an engraved impression in almost every technical field such as in engineering, medical (deontology, dermatology, ophthalmology) etc. Retinal fundus images are important for ophthalmologist to find out the various diseases. Images are difficult to detect as they are corrupted with contrast variability and high luminosity. Contrast enhancement is one of the image processing technique used to improve the digital quality of the image. Therefore, this paper evaluates the performance of contrast enhancement methods on the blood vessels retinal images. Further, these images are examined by different methods such as HE, AHE, CLAHE, Rayleigh CLAHE, non uniform sampling and VE-MSC to validate the results. It has been observed that VE-MSC improves the image contrast and gives more details of vascular structure, provide appropriate results in green plane than the other two planes (Red and Blue) to enhance the color retinal image quality.

Keywords: Blood Vessel, Contrast Enhancement, Digital Image Processing, Retinal Image.

I. INTRODUCTION

Digital image processing is the use of algorithms in computer to perform image processing on various digital images. An image may be defined as a two dimensional function, f (x, y) where x and y are spatial (Plane) coordinates, and the increase of f at any pair of co-ordinates (x, y) is called the intensity or grey level of the image at that point [1].

The retina is light sensitive tissue located at the back of the eye. Retinal images are important for ophthalmologist to identify, detect and diagnose many diseases such as diabetes, hypertension, cardiovascular diseases and stroke. Nowadays, retinal images are widely used manually and automatically by using image processing technique known as computer aided diagnosis (CAD) e.g. Flood imaging, optical scanning laser opthalmoscopy, optical coherence tomography etc. [2][3][5] Glaucoma, cataracts and diabetes are the symptoms that can distort the patient's vision and are the main causes of blindness.

Some important components in retinal image are - Optic disc, Fovea, Macula and Blood vessels. The human body contains different types of blood vessels which comprise a network of arteries and veins [5]. A small change in blood vessel structure of retinal images often leads to diseases [7]. The problem of diabetes causes changes in the blood vessels of the retina which is known as Diabetic Retinopathy.

Retinal Photography is obtained by using a fundus camera that takes image of the interior surface of the eye [7]. The use of fundus camera consumes less time and is less expensive [14]. Retinal image has unique characteristic that it provides us more precise results in green plane than the other two planes (Red and Blue) [10].

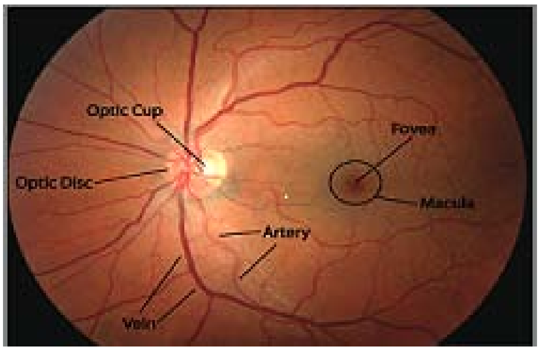
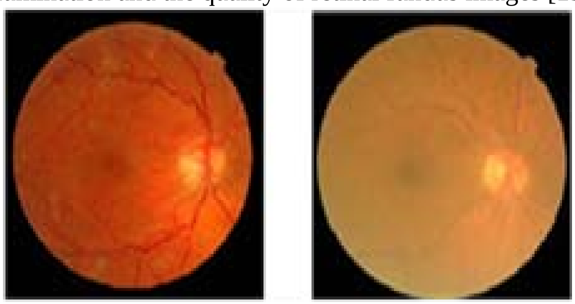


Fig. 1. Retinal Fundus Image with various component

II. CONTRAST ENHANCEMENT

Contrast enhancement technique has an important role in the field of retinal image enhancement as it improves the contrast of an image. The contrast is an important factor to differentiate a good quality image from a low quality image [17]. It is a combination of the range of intensity value and differentiation of the maximum and minimum pixel values [2]. Therefore, this paper presents contrast enhancement methods to correct the illumination and the quality of retinal fundus images [13].



a) **Normal eye** **b) Poor equality**

Fig. 2. Color Retinal Images

III. CONTRAST ENHANCEMENT TECHNIQUES

Generally, the contrast enhancement methods can be categorized into different classes such as Histogram Based, Transformation Based, Masking Based and Filter Based [5,10]. But this review paper represents Histogram Based methods such as Histogram Equalization (HE), Adaptive Histogram Equalization (AHE), Contrast Limited Adaptive Histogram Equalization (CLAHE), Rayleigh Contrast Limited Adaptive Histogram Equalization (Rayleigh CLAHE), Non Uniform Sampling, Vessel Enhancement Via a Multi-dictionary and Sparse Coding (VE-MSC).

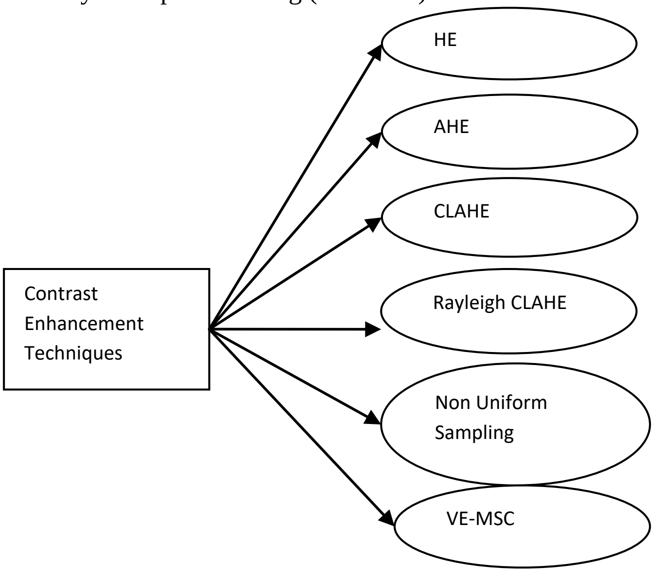


Fig. 3. Contrast Enhancement Techniques

A. Histogram Equalization

Histogram Equalization (HE) is one of the contrast enhancement method which has low computation load. This technique improves the appearance of image by distributing the intensity values of the pixels uniformly (i.e. a flat histogram) However to get a perfect image, it is essential to have equal no. of pixels in all the gray levels. Hence, it becomes necessary not only to have uniform distribution but also to have equal no. of pixels in all the gray levels [15]. It is one the most simple and easy method for retinal image contrast enhancement. Therefore, HE is not a good technique for retinal images due to its high intensity noise and the absence of some brightness levels even after applying the enhancement method. It produces good results in ordinary images such as human portraits or natural images [3, 9]. HE provides the little improvement on the component, blood vessel of the retinal image.

B. Adaptive Histogram Equalization

Adaptive Histogram Equalization (AHE) is based on Histogram Equalization (HE). This method develops each histogram of sub-image in order to redistribute the brightness value of the images [3]. Although, Histogram Equalization (HE) works on the full image but it provides less improvement. In contrast to HE, Adaptive Histogram Equalization (AHE) improves the local contrast of a retinal image in blood vessel. Hence, AHE brings out more details than HE [15].

C. Contrast Limited Adaptive Histogram Equalization

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a contrast enhancement method which develops from AHE method [16]. It is a method for retinal vessel enhancement AHE showed amplifying noise in some of the homogenous regions, thus to eliminate this problem CLAHE was proposed. In CLAHE the input image is splitted into three image channels [Red (R), Green (G) and Blue (B)]. CLAHE is carried out only in the G channel as this channel supports important blood vessel structural information. Thus, an enhanced G channel is obtained. Finally R, enhanced G, B channels are merged together to produce an enhanced color retinal image[2]. Due to blurred boundaries of retinal vessels with low contrast and strong noise resulted from retinal image collection, it is not easy to extract vessels automatically from retinal images. From the visual observation, in Red channel there is more noise in the image than input image. In Blue channel, image qualify tends to be poor than the original one. In Green channel, structural image information gives more contrast than the original one as shown in Figure 4.

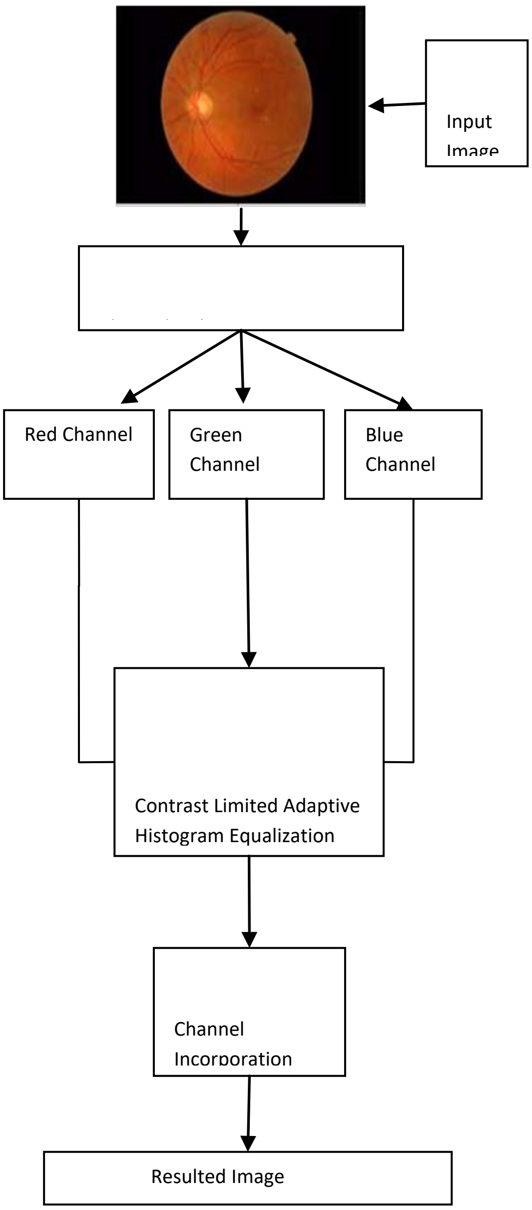


Fig. 4. Enhancement Flowchart

D. Rayleigh Contrast Limited Adaptive Histogram Equalization

The intensity component is enhanced by Rayleigh transformation in Contrast Limited Adaptive Histogram

Equalization (Rayleigh CLAHE) [3]. In CLAHE the image has good contrast but it does not preserve the chromatic information. In Rayleigh CLAHE, it keeps a good contrast of blood vessels as well as preserves chromatic information in retinal image. Thus, it improves the overall appearance.

E. Non Uniform Sampling

This method is based on the retina geometry and imaging conditions of blood vessel of an image. Most of the retinal images suffer from non-uniform illumination. Non-uniform sampling method finds the correction factor using the estimation of the degradation components. The normalized correction factor when applied on all three (R, G and B) planes improved the contrast for non-uniform illumination successfully. Thus, it improves the overall contrast and provides a nominal shift in the color content. So, no new artifacts were introduced [4].

F. Vessel Enhancement via multi-dictionary and sparse coding

In this method, two corresponding dictionaries are generated one is the Representation Dictionary (RD) and the other one is the Enhanced Dictionary (ED). The patches in RD and ED are selected through the information images to optimize the multi-dictionary. The gray level image is represented by RD and label image is represented by ED to get the sparse coefficients via a sparse coding process. The patches are extracted only by the use of green channel. This method not only improves the image contrast but also enhances the retinal vascular structure. Hence, it provides more details of retinal images [5]. Therefore, Best results were obtained in this method.

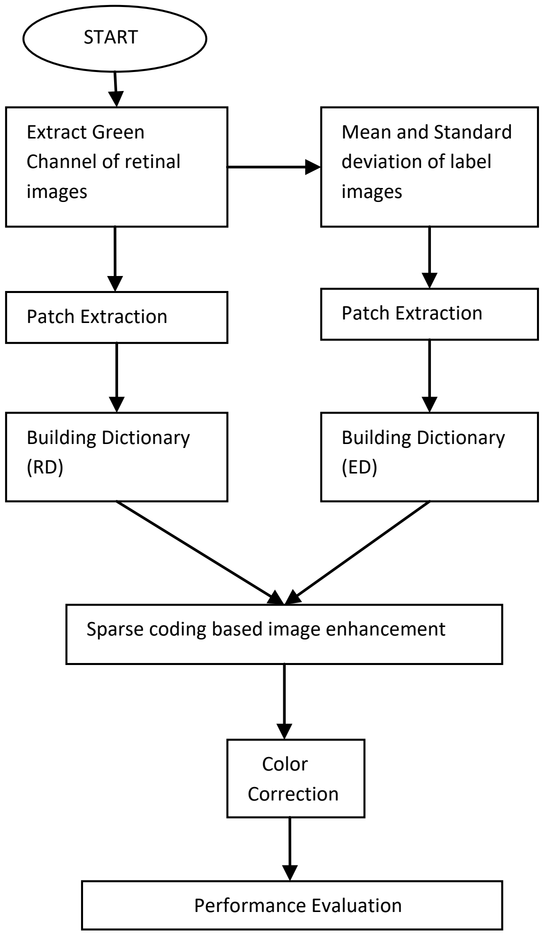


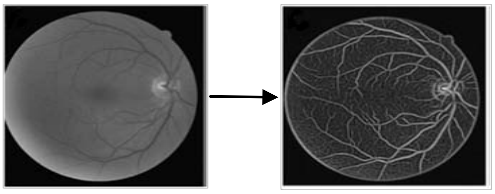
Fig. 5. Flowchart

TABLE.1 A summarized comparative chart of the histogram-based contrast enhancement methods has been explained:

Methods	Keywords	Advantages	Disadvantages
HE [3,9,15]	Retinal Imaging, Color enhancement	Simple & low computation load	High noise and absence of some brightness level
AHE [3,15]	Noise, Image enhancement, Brightness values	Improves local contrast, Brings out more details	Amplifying noise
CLAHE [2,16]	Retinal image, Color, Contrast enhancement	In G channel, it produces more contrast than other two (i.e. R & B) channels.	Chromatic information is not preserved.
Rayleigh CLAHE [3]	Diabetic Retinopathy, retinal image, illumination	Preserves chromatic information & improves overall appearance	Suffer from non-uniform illumination
Non-uniform sampling [4]	Fundus camera, Retina, Image Enhancement, color, artifacts	Normalized correction factor in all three planes (R, G, B) & correction of non-uniform illumination, minimal shift in color content & no new artifacts introduced	Lesser details of vascular structure of retinal images.
VE-MSC [5]	Blood vessel enhancement, multi-dictionary, sparse coding	Effectively improves the image contrast and gives more details of vascular structure of retinal image	Extending to other image enhancement problems.

IV.CONCLUSION

In this paper, an attempt is made to evaluate the performance of vessel enhancement. From best of our knowledge a vessel enhancement method (VE-MSC) via multi-dictionary (RD and ED) and sparse coding is developed by a patch selection. The sparse coding has been used for blood vessel enhancement specially the green channel enhancement. It improves the image contrast and gives more details of vascular structure of retinal image.



a) Poor Quality b) Enhanced Image

Fig. 6. Retinal Images [5]

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