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Color Fundus Image Enhancement and Segmentation using Bitplane Extraction and Color Component Clustering

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ABSTRACT. *Retinal image is the most essential one that helps in detection of many critical diseases like diabetes, muscular degeneration etc. There are also many algorithms that can classify the diabetes as Type 1, Type 2, etc. To felicitate this kind of operation a crystal clear picture of Retinal Images should be provided as input to these algorithms. Basically there are several influential factors that distort Retinal Fundus Images while it is being captured. Once the image is distorted, it will be a hectic task to implement those algorithms. Hence there is a need to enhance these particular images. There are many techniques available for enhancing the Retinal Images. In this article one such novel algorithm is proposed to enhance and to segment the retinal image. This algorithm involves the enhancement of Retinal Fundus Images. The algorithm involves Luminance enhancement and Contrast enhancement using Image Fusion Technique. Here CLAHE (Contrast Limited Adaptive Histogram Equalization) algorithm is used to enhance the contrast of the image. Once the image is enhanced it is then the Color Component Clustering Algorithm is used to segment the image after the bitplane extraction. Here a dataset of 1200 retinal images are taken and evaluated using the proposed algorithm. All the considered images are poor and average quality images. The proposed algorithm is also compared with the literature, and it is found to be the most superior algorithm of all. The Quality assessment in the range of 0 to 1, of this poor image dataset has been improved from 0.0404 to 0.4685 with a standard deviation of 0.0955 (Which is 0.1000 in earlier case).*

Keywords: Retinal Fundus Image; luminance; contrast; enhancement; bitplane extraction; segmentation; color component clustering; power law transformation

1. **Introduction.** Retinal Fundus Images are most popularly utilized by ophthalmologist for various diagnostic purposes. These retinal images are used specifically for early detection of Diabetes and muscular degeneration. For effective analysis and diagnostics, a

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distortion free image should be considered. In case of any distortion is present in the image taken into consideration, it may lead to false diagnostics. Hence one should be conscious in analyzing the images, since we may not be aware of which noise is and which original image is. Hence, a properly emphasized procedure is to be employed to remove the distortion from these images. In other words, all the necessary steps are needed to be taken to enhance the image to the best possible extent.

There are several factors responsible for introducing noise into the image. They are improper illumination, improper focusing, blurring etc. Also, if the image's contrast is low then the image becomes improper for diagnostics. This causes the ophthalmologists difficult in extracting considerable features from the retinal image. Hence it is difficult for them to diagnose the problem using retinal images.

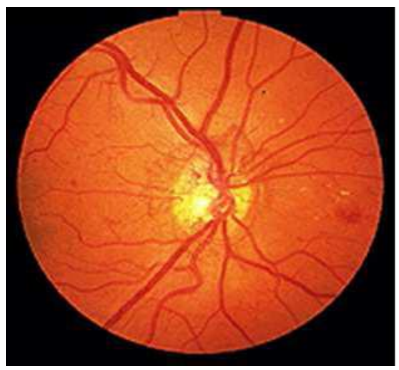


Fig. 1. Fundus Image of a patient with diabetic retinopathy

There are different possible solutions available to enhance retinal images. They include histogram equalization [9], normalization of luminance, contrast enhancement, a technique based on Contourlet Transform, contrast limited adaptive histogram equalization technique, multiscale top hat transformation, sparse coding, Gaussian Filtering.

These methods when applied to the color images loose certain information, and hence at many times many significant information was lost, which plays a most crucial role in diagnostics.

In this article a novel algorithm is proposed, in which at first the image is extracted as RGB Components, and then Gamma Correction is done independently to each images so as the luminance of the image is improves, and then finally they are merged. Once this happens again the resultant image is separated into components and the contrast is enhanced by using the CLAHE algorithm. Finally, all the images are fused together so as to provide the resultant enhanced image. Once the image is enhanced, image is segmented so that the defects in blood vessels could be recognized very easily. Here initially bitplane extraction is done so as to obtain a well-defined grayscale image in which every single information is preserved. Now the Color Components Clustering method is applied over the bit plane extracted gray scale image.

2. Materials and Methods.

2.1. **Retinal Image Fusion using HSI Technique.** Normally, it is difficult to get a good quality image using a single shot capture. It may cause improper focusing of the image. To resolve this issue, a number of times an image are captured with different center of focus, and finally all the images are combined together. This process of combining all the copies of a same image is called as Image Fusion Technique. The objective is not to lose any of the information from the captured image. There are several different types of Fusion Techniques such as Single level Fusion, Pixel/Data level fusion, feature level fusion, and decision level fusion. Here we use a fusion methodology namely Intensity Hue Saturation (IHS) Image Fusion Method [11], where the Red Green and Blue component of Multispectral Image are transformed to IHS Component. This increases the quality and accuracy of the image to ensure that none of the information in the image got lost during the capturing process.

2.2. **RGB Plane Extraction.** Here the dataset which is taken into consideration for our experiment consists of retinal fundus images that are of poor and average quality. The total count of dataset is 1200. These were taken by a TRC-NW8 Fundus Camera with a resolution of 2144 x 1424 Pixels. Some of the samples from the dataset are shown in the figure 2.

Fig. 2. Sample images from retinal dataset

The first step in implementing the proposed algorithm is the extraction of the different color components from input image. There are many different color components in a color image. The accuracy of enhancement increases with increase in the number of color planes that are extracted. But for simplicity we are limiting ourselves to the basic three color planes such as Red Plane, Green Plane, and Blue Plane. The input color image is extracted as these three-color plane images.

2.3. **Retinal Image Enhancement.** Image enhancement is the important phase of implementation where the undesirable image is made into a desirable image so that it could be binarized easily. Once it is binarized all the defects in the eye blood vessels could be recognized very effectively. There involve two different phases in the proposed enhancement technique. At first the luminosity enhancement is done and then contrast enhancement is done.

2.4. **Luminosity Enhancement.** There are basically three different planes of color image taken into consideration: Red, Green and Blue Planes. All these planes contain the different luminous information that is correlated within each other. It is necessary that the luminosity of the color image has to be adjusted so that it would assist in providing all the information related to diagnosing various defects. Also it is mandatory that the luminosity values should be varied proportionately in all the considered color planes. It is done by deriving luminance gain matrix.

$$\frac{r'(x,y)}{r(x,y)} = \frac{g'(x,y)}{g(x,y)} = \frac{b'(x,y)}{b(x,y)} = G(x,y)$$

Here the matrix is obtained by transforming the image into the HSV image. In HSV image H and S do not play any role in influencing the luminosity. Only V (Luminous Channel) is taken into consideration for luminous adjustments. Now gain matrix is obtained by dividing the effective luminosity value by max of [*R(x,y), G(x,y), H(x,y).*

Here Gamma correction is as follows:

$$w = u^{\gamma}$$

Here *W* is the normalized output. Normally the Gamma value is greater than 1. The optimum value is chosen to be 2.2. Finally the enhanced images are obtained as values $r'(x, y)$, $g'(x, y)$, and $b'(x, y)$.

2.5. **Contrast Enhancement.** The low luminous retinal images are enhanced using the above luminosity enhancement technique. Further the contrast of the image should be modified so that the image is enhanced further for easy detection of defects in blood vessels. It could also help in proper binarization of image. Here we use CLAHE method for enhancing the image. Here initially the L*a*b color space is obtained for the Red, Green and Blue color components. In this CLAHE method of contrast enhancement, the image is divided into small segments, in which the histogram equalization is done independently. This technique removes the local noise and produces an enhanced image. In this implementation of CLAHE, we have employed clip-limitation, with a clip-limit of 0.02, under Rayleigh distribution.

Once the Contrast Limited Adaptive Histogram Equalization is done in CIELAB, the image is transformed back in RGB color space, in which each of the color components are contrast enhanced and it is indicated as *r'(x,y), g'(x,y) and b'(x,y).* The contrast enhancement thus done is very effective after luminosity enhancement comparing to the CLAHE done without luminosity enhancement.

2.6. **Segmentation on Bitplane Extracted Grayscale Image using Color Component Clustering.** Before segmentation, it is necessary to ensure that no information is lost during the segmentation process. In order to ensure that, bitplane extraction is done in which image extraction is done from 0^{th} Plane upto 7^{th} plane and then finally all the bitplane images are combined together to provide an effective grayscale image with all the information preserved. There are many methods that are available to segment an image. In our proposed techniques we use the Color Components Clustering technique [1]. This method holds good for even noisy image segmentations. Here according to the algorithm, the bitplane extracted grayscale image extracted into Red, Green and Blue planes and then canny edge detection is performed on each of the images, and they are independently binarized with local equalization value with reference to the Edge box created. There are certain constrains forced over the Edge box aspect ratio which is obtained from the literature. In each independent Edge boxes, Power Law Transformation is used to binarize them locally. Here global binarization may cause certain information to get lost. So as to preserve every single information of the retinal blood vessels, the binarization is done independently within the each edge box. The threshold value is obtained by:

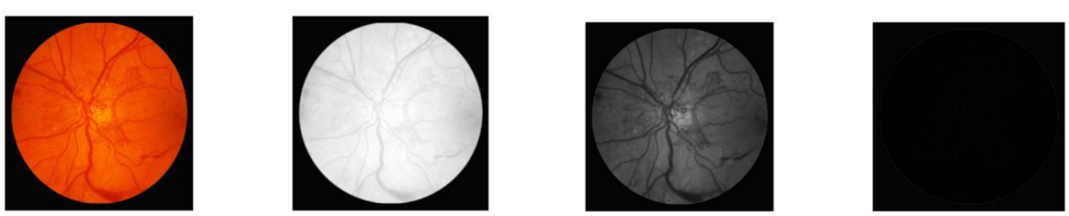
$$\sigma^2(k^*) = \max_k \frac{[\mu_T\omega(\mathrm{k}) - \mu(\mathrm{k})]^2}{\omega(k)[1-\omega(k)}$$

Where,

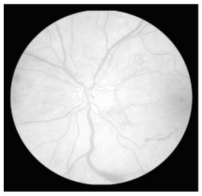
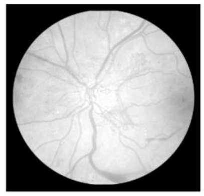
$$\omega(k) = \sum_{i=1}^{k} p_i \; ; \mu(k) = \sum_{i=1}^{k} ip_i \; ; \mu_T = \sum_{i=1}^{k} ip_i$$

MATLAB R2014b on a PC with Intel i7 processor at 2.20 GHz with 8GB RAM is used to implement all the above operations.

3. **Results and Discussion.** A Typical fundus images is considered. It is processed through the proposed algorithm. The results obtained at each stage of processing are shown below.



[a] [b] [c] [d]


[e]

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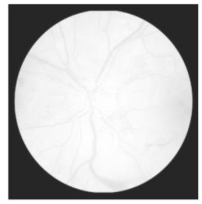
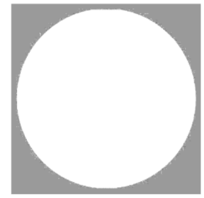
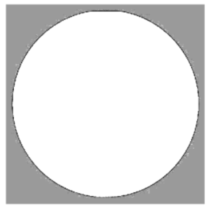
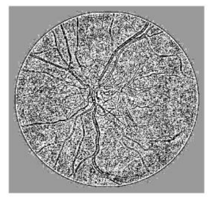

[g]

[h]

[i]

[j]

Fig. 3.Processing stages for input Image [a] Input Image, [b] R Component Image, [c] B Component Image, [d] G Component Image, [e] HSV Image, [f] Gamma Corrected Image, [g] G Matrix Image, [h] R Dash Component Image, [i] B Dash Component Image, [j] G Dash Component Image.


[a]

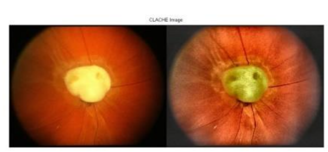
[b]


[c]

Fig. 4.[a] Luminance Enhanced Image, [b] Contrast Enhanced Image using CLAHE, [c] Input Output Comparison.

Some of these input and enhanced images are shown in Figure 4. (In Figure, the images in Right side are Input image and the images in left side are Output Enhanced Image).





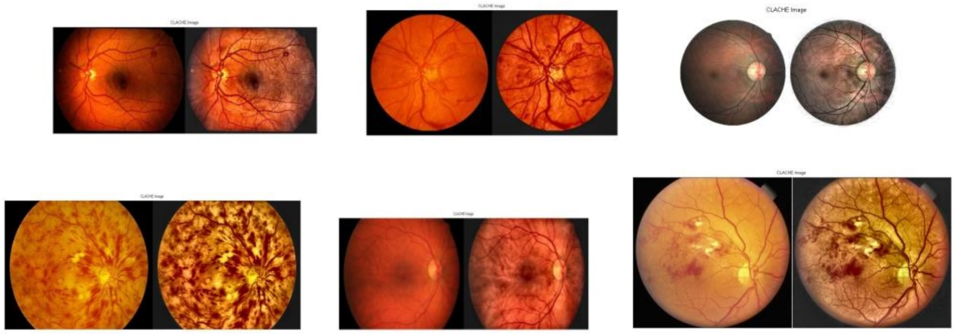


Fig. 5.Input Fundus Image [On left side of each image] and Enhanced image [On the right side of each image]

Once the enhancement process is completed, the image should be further processed for segmentation. It includes bitplane extraction of the grayscale image. Here upto 7th plane extraction happens and then all the extracted plane images are combined to form a gray scale image

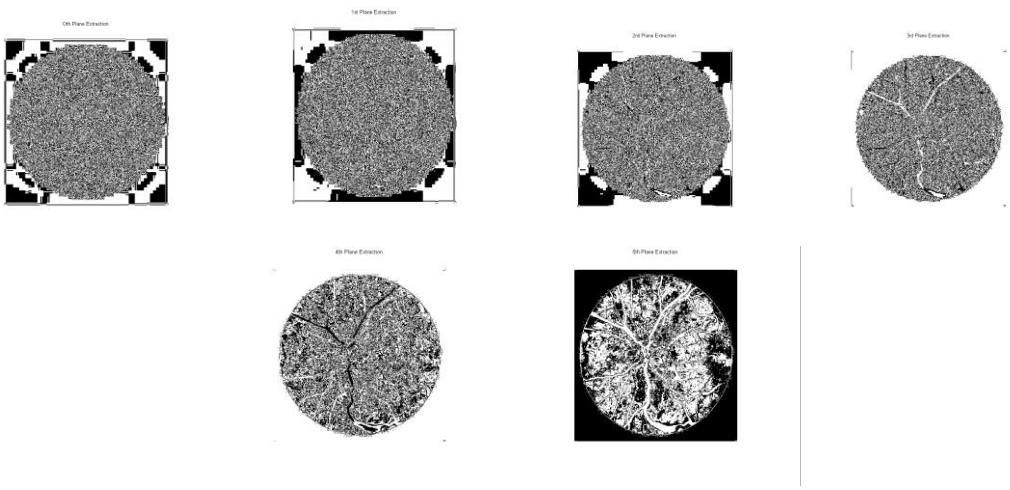


Fig. 6. Some of the bitplane extracted images. They correspond to 0th to 7th plane extractions.

Fig. 7. Bitplane extracted images are combined to form the enhanced grayscale image.

Now on this enhanced gray scale image, Color component clustering based segmentation is done. The various planes of images are extracted, and canny edge detection is done. Also independent edge boxes are created to binarize the image independently as shown below.

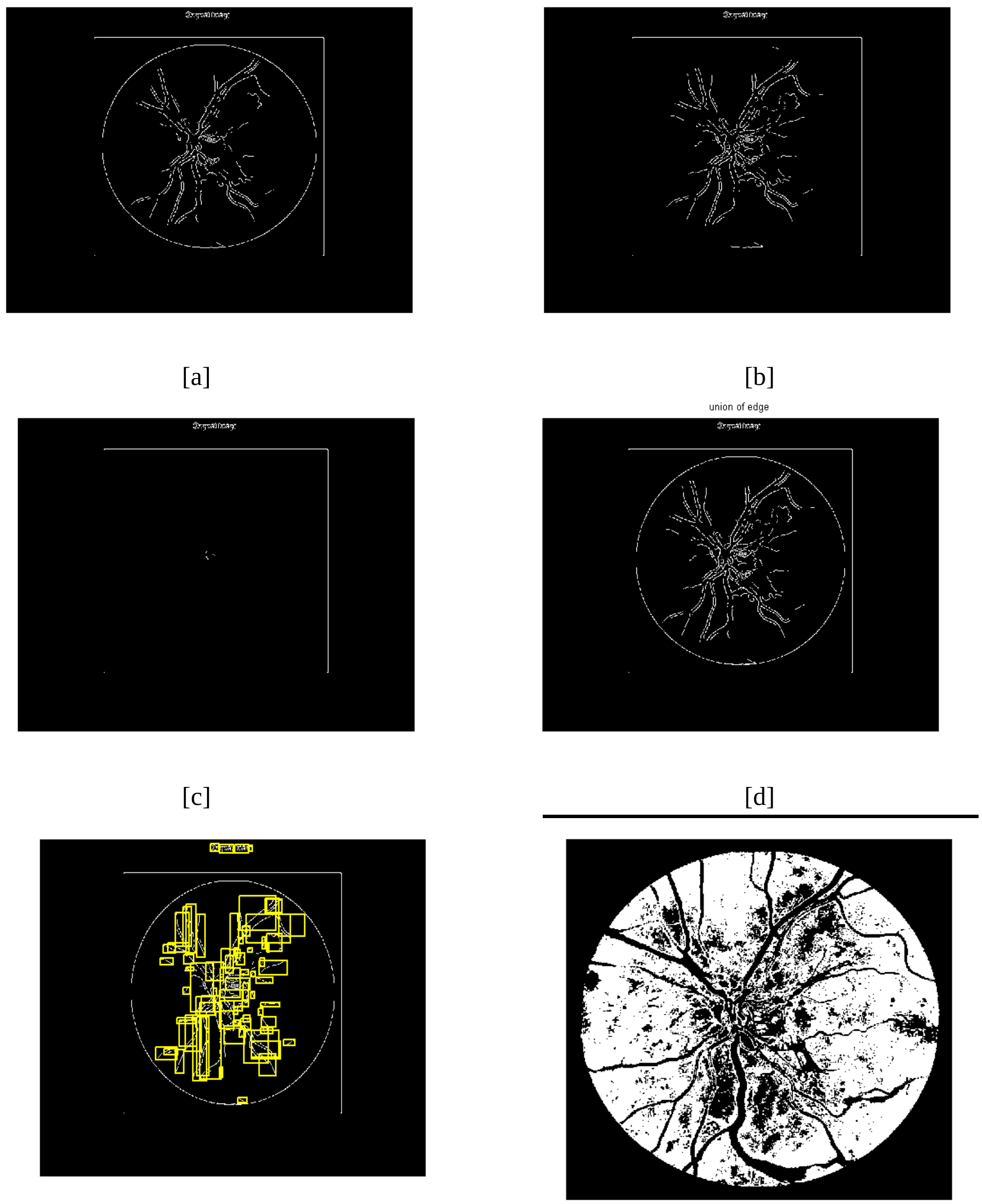


Fig. 8.[a] Red Plane Image; [b] Green Plane Image; [c] Blue Plane Image; [d] Union of Plane Images; [e] Edge box Image; [f] Segmented Image.

Now furthermore example retinal Fundus Images are taken into consideration, and the above discussed processes are implemented. A Dataset of 1200 Images has been considered for this operation. The difference between the normal segmentation and the proposed segmentation process is that in case of normal segmentation, a huge amount of information gets lost during the implementation. But in the proposed system, due to many stage of processing very minimal information is lost.

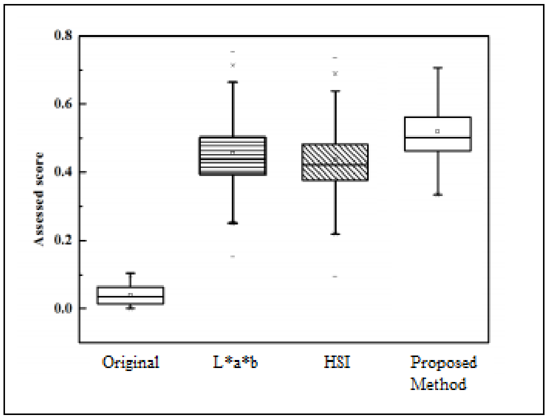


Fig. 9. Boxplot Comparison of accessed scores of images by various techniques with the proposed technique.

The above Boxplot comparison delivers a detailed picture of the proposed technique in comparison with the techniques in literature. The comparison happened through the Assessment score on the scale of 1. The proposed technique calculates to 0.55 which is 0.45 in case of HSI and 0.47 is case of L*a*b. Also, in previous cases, many images do not behave well for the segmentation process. But in the proposed technique almost 90% of the images behaved well. It is also found that Average score is 0.0426 and the Standard Deviation is about 0.0786.

4. **Conclusion.** An effective and efficient method for enhancing and segmenting the retinal image is proposed, which uses contrast and luminosity techniques for enhancement. It also uses bitplane extraction and color component clustering algorithms for the purpose of segmentation. Due to several stage of processing, we can ensure than only minimal information is lost during the processing. Almost all of the information is preserved when the retinal fundus image is processed using the proposed technique. Also the analysis has shown that the proposed technique is better than many techniques reported in the literature. The Boxplot comparison of Assessment scores shown in Fig.9 depicts the efficiency of the proposed technique. The proposed technique has the Assessment score of about 0.55 which is less in previous cases. The segmented retinal image could assist the ophthalmologist in detecting various defects in blood vessels, and also in determining various other defects. The technique can further be exhaustively studied and used for exactly extracting the blood vessels for further study and analysis, which could lead to automatic identification of various

defects that could be diagnosed with the help of the Retinal Blood Vessels. Further this technique could be used for much effective implementation of automatic diabetes detection and classification. Though the method is effective, still image fusion is a tedious and complex process and hence the alternative implementation of this technique without the use of image fusion should be examined.

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