Comparative Analysis and Implementation of CLAHE with Proposed Technique in Retinal Images

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The human eye is the most critical part that can be adversely affected by diabetes in the near or long run. The detection of DR (Diabetic Retinopathy) in the early stages is not that easily possible. The detection of DR primarily depends on the quality of the retinal images of the diseased person. The higher is the quality of the retinal image, the more are the chances of detection of abnormalities. The research paper elaborates on the popular CLAHE (Contrast Limited Adaptive Histogram Equalization) technique been used for enhancing the contrast of the retinal images. The research paper also anticipates a technique intended for enhancing the quality of the retinal images. The retinal images are obtained from the DRIVE (Digital Retinal Images for Vessel Extraction) dataset. The quality of enhancement achieved by using both techniques is compared and measured using three performance metrics of MSE (Mean Square Error), PSNR (Peak Signal Noise Ratio), and RMSE (Root Mean Square Error). PSNR is considered as the prominent performance metric to decide the degree of enhancement achieved. Greater is the value of the PSNR, higher is the degree of enhancement. The comparative analyses between the PSNR values obtained from both the techniques have been conducted and it has been found that the proposed technique outperforms CLAHE in enhancing the retinal images.

Keywords: Blood vessels, CLAHE, DRIVE, Enhancement, PSNR.

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1 Introduction

Diabetic retinopathy is a disorder in the human eye responsible for vision loss and blindness in people suffering from diabetes. Diabetic retinopathy makes a negative impact on blood vessels in the retina. The initial phases of diabetic retinopathy typically don't have any indications [1]. Some people notice variations in their vision, like trouble, reading, or sighting distant objects. These changes may come and go. In advanced phases of the disease, blood vessels start bleeding into the enamel (gel-like liquid) that blocks one's vision [2, 3]. This may cause darkness, and one might witness moving spots or strips that look like cobwebs. The research papers recommend a technique envisioned for accomplishing the enhancement of retinal images so that a healthier image can be progressed to advanced stages like segmentation and classification [4, 5]. The worth of the steered research effort is dignified via three performance appraisal metrics - MSE, PSNR, and RMSE. The MSE signifies the cumulative squared error between the compressed and the original image [6]. The lower the value of MSE, the lower is the error. PSNR is defined as a value envisioned for the measurement of quality between the original and compressed image [7, 8]. PSNR is a proportion amid the maximum likelihood values of a signal to the effect of the fabricating noise that distracts the quality of its demonstration [9, 10]. The more is the value of the PSNR, the greater is the quality of the obtained image. Root Mean Square Error (RMSE) is the square root of the mean of the square of all of the errors [11, 12]. Out of the three performance metrics, PSNR is the prominent metric that indicates the quality of the enhanced retinal image [13].

2 State-of-the-Art

In 2019, Sundaram et al. [14] stated that the main cause of Diabetic Retinopathy is the change in the blood vessels. Over time diabetic retinopathy may get worsen and results in permanent vision loss. The authors recommended a hybrid segmentation algorithm intended for extracting the blood vessels from retinal images. The anticipated algorithm collaborated with techniques like BHT (Bottom Hat Transform), MO (morphological operations), and MSVE (Multi-Scale Vessel Enhancement) algorithm. The author made use of the DRIVE, CHASE and STARE databases. Finally, the output is equated with the High-Resolution Fundus (HRF) images dataset. It was verified that the anticipated algorithm segments the blood vessels with higher accuracy as compared to the prevailing algorithms. In 2020, Bala et al. [15] suggested that Fundus images are generally used by ophthalmologists to investigate any type of abnormalities. Fundus images have some disadvantages like low contrast and noisy information, which causes a hurdle in the accurate investigation of the disease. The authors suggested a technique and named it Adaptive Histogram Equalization—Tuned with Non-similar Grouping Curvelet (HET-NOSCU). PSNR (Peak Signal to noise ratio), (SSIM) Structural Similarity Index, and CoC (correlation coefficient) were calculated to check the enhancement achieved. The proposed adaptive histogram equalization was adjusted with a nonsimilar grouping curvelet (HET-NOSCU). It handles the noise in the retinal image. HET- NOSCU has attained a maximum PSNR value of 43.9539, SSIM value of 0.9809, and CoC value of 0.9983 at noise level 0.005.

In 2021, Sheeta et al. [16] stated that any type of infection in retinal tissue may cause permanent vision loss. The authors suggested a fully automatic multi-class retina diseases forecast technique to help ophthalmologists to diagnose the exact problem. The author made use of the STARE database which includes five classes: BDR, CRVO, CNV, PDR, and Normal. Firstly, these images were refined with the help of a contrast-limited adaptive histogram which included brightness, noise reduction, and intensity spectrum normalization. The proposed model attained 100% sensitivity, 100% specificity, and 100% accuracy. In 2021, Bala et al. [17] retinal fundus images are regularly used by Ophthalmologists to examine and identify diseases related to the retina. Generally, fundus cameras are not fully capable to catch high-resolution retinal images because of camera quality, eye movement, irregular illumination, etc. The author emphasized the adaptive sigmoid mapping of histogram equalization and multi-resolution curvelet transform intended for the enhancement of retinal images. Performance metrics like PSNR, SSIM, and CoC were calculated. The author calculated Noise Variance Median+ CLAHE, Weiner+ CLAHE, Gaussian filter + CLAHE also with the proposed method. Finally, it is provedthat the suggested algorithm performs better in pre-processing of color fundus images. Hybrid technique attained PSNR of 6.85%, SSIM of 0.89%, and CoC of 0.13% compared to existing methods with Gaussian noise of about 0.01.

3 Research Methodology

This section focuses on detailing the enhancement techniques for retinal images. A research methodology has been anticipated for performing the enhancement of the retinal images obtained from the DRIVE (Digital Retinal Images for Vessel Extraction) dataset. The proposed methodology has been compared with the CLAHE (Contrast Limited Adaptive Histogram Enhancement). The PSNR (Peak Signal Noise Ratio), MSE (Mean Square Error), and RMSE (Root Mean Square Error) have been computed via comparing the enhanced retinal images obtained with both the techniques with the original retinal images to prove the worth of the conducted research. The anticipated model is predominantly constructed on steering the blood vessels extraction from the retinal images. The emphasis has beenlaid on blood vessels because these vessels are a precarious part of the retina and the state of these vessels directlyspecifies the level of impairment the human eye is facing.

Fig. 1 represents the detailed working of the proposed methodology for conducting the enhancement of the retinalimages followed by an appropriate flowchart.

Algorithm

- Read the RGB input image *I*.
- Initialize the parameters.
- Implement the Green Channel on *I* and plot a histogram.
- Perform processing and eliminate the edges from an image *I* to obtain image *Ip*.
- Save Result of line tracking.
- Execute morphological directional filtering at 0, 30, 60, 120, and 150 degrees on the image *Ip*.
- Execute median filtering on the image *Ip*.
- Convert *Ip* to the binary image *Ib* as output.
- Perform map Quantization and obtain the image *Iy*.
- Convert the input image *I* into binary image *Ix*.
- Compare the images *Ix* and *Iy* and calculate the values of PSNR, MSE, and RMSE.

  End

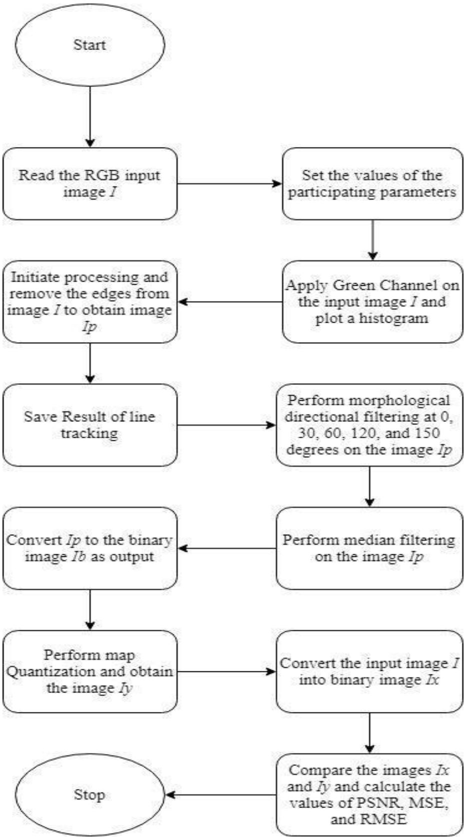

Fig. 1. Flowchart depicting working of the proposed methodology

4 Implementation and Results

This section focuses on the implementation of the research methodology proposed in Section III. The retinal images have been provided as input to the CLAHE and the values of performance evaluation parameters have been computed. A GUI interface has been constructed to depict the procedure adopted for enhancing and extracting theblood vessels from the retinal images. The retinal images have been obtained from the DRIVE dataset. Five different cases have been elaborated via appropriate images intended for enhancing and extracting the blood vesselsas per the proposed methodology. The results have been obtained for 5 retinal images from the DRIVE dataset forboth the techniques been studied.

Fig. 2. Figure shows the input retinal image *"31_training.tif"*

After running CLAHE on the input image, the images are shown in Fig. 3 (a) and Fig. 3 (b) is obtained. Fig. 3(a) shows the corresponding Grayscale image and Fig. 3(b) represents the final contrast-enhanced image obtained aftercompletion of the enhancement process as per CLAHE.

Fig. 3 (a). Gray scale image **Fig. 3 (b).** Contrast enhanced image

Results:
MSE = 3.8355
RMSE = 1.9585
PSNR = 36.45

Fig. 4 shows the designed GUI interface. The interface has been divided into four sections. The left panel shows the push buttons to initiate actions related to browsing for an input retinal image (Browse), initiating the technique(Initiate Analysis), refreshing the scenario (Refresh), terminating the ongoing process permanently (Close), and obtaining the final result (Final Result).

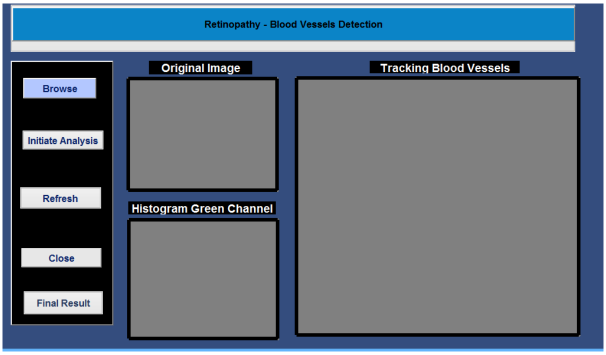

Fig. 4. Figure depicts the constructed GUI for executing the proposed methodology

Fig. 5 shows the input image "31_training.tif" been uploaded onto the designed GUI after browsing it.

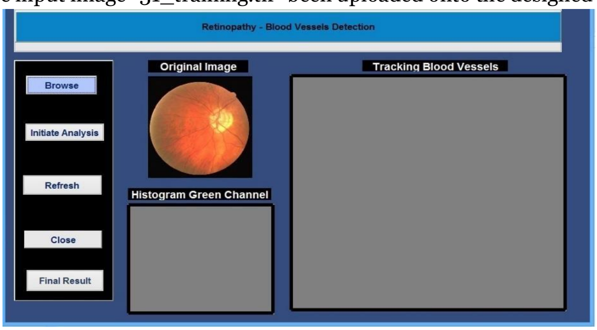

Fig. 5. Figure demonstrates the uploaded input image *"31_training.tif"* onto the designed GUI

Fig. 6 demonstrates the obtained Green Channel Histogram as a result of the initiated analysis.

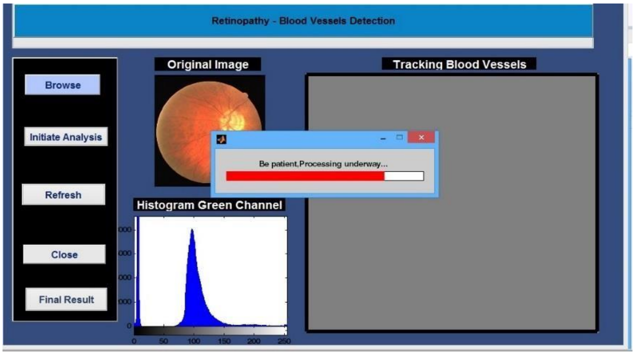

Fig. 6. Figure demonstrates the obtained Green Channel Histogram as a result of the initiated analysis

Fig. 7 depicts the extracted blood vessels from the retinal image under study.

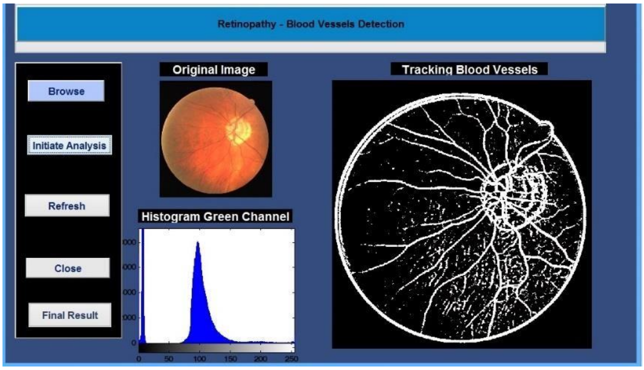

Fig. 7. Figure depicts the blood vessels been extracted from the retinal image understudy

Fig. 8 shows the final quantized image obtained after the completion of the adopted technique.

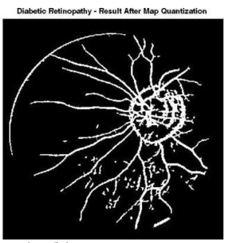

Fig. 8. Figure shows the finally obtained quantized image

Results

MSE =3.9599

RMSE = 1.9900

PSNR = +42.70 dB

Table 1 shows the obtained readings of different performance evaluation parameters after applying CLAHE. Thevalues have been obtained for 5 retinal images from the DRIVE dataset.

Table 1. Table shows the obtained values of performance evaluation parameters via CLAHE

Image Name	MSE	PSNR	RMSE
31_training.tif	3.8355	36.45	1.9585
32_training.tif	3.9574	36.18	1.9893
33_training.tif	3.9956	36.10	1.9989
34_training.tif	4.0162	36.05	2.0041
35_training.tif	4.1665	35.74	2.0412

Table 2 shows the obtained readings of different performance evaluation parameters after applying the proposedtechnique.

Table 2. Table shows the obtained values of performance evaluation parameters implementing the proposed technique

Image Name	MSE	PSNR	RMSE
31_training.tif	3.9599	42.40	1.9900
32_training.tif	3.8958	42.83	1.9738
33_training.tif	3.9713	42.67	1.9928
34_training.tif	6.1571	38.76	2.4813
35_training.tif	4.5948	41.46	2.1436

5 Conclusion

The research paper focused on implementing CLAHE and proposing an enhancement technique for augmenting the retinal images. PSNR is considered as the prominent evaluation parameter for evaluating the enhancement performed on different retinal images. The greater is the value of the PSNR, the more is the enhancement achieved.The comparative analysis of PSNR for 5 different retinal images from the DRIVE dataset has been conducted in Table 3 below. The value of PSNR is higher for the 5 retinal images in the case of the proposed technique.

Table 3. Table depicts the computed PSNR values for 5 retinal images via CLAHE and Proposed Technique

Image Name	CLAHE_PSNR	Proposed Technique_PSNR
31_training.tif	36.45	42.40
32_training.tif	36.18	42.83
33_training.tif	36.10	42.67
34_training.tif	36.05	38.76
35_training.tif	35.74	41.46

Fig. 9 demonstrates the comparison of the PSNR values for 5 considered images using CLAHE and the proposed technique. The high altitude histograms for the five retinal images in the case of the proposed technique prove theworth of the conducted research.

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Fig. 9. Figure demonstrates the comparison of the PSNR values for 5 considered images using CLAHE and the proposed technique

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