

Improved Oct Image Enhancement using Clahe

Saya Nandini Devi M, Santhi S



Abstract: Medical image processing is a challenging research field, since most captured images suffer from noise and poor contrast nature. The accuracy of details present in the medical image depends entirely on the captured image quality. The factor that affects the quality of the images includes poor illumination conditions, capturing devices and inexperienced technicians that may result in low contrast images. Hence, contrast enhancement techniques are necessary to improve the quality of OCT images for further processing. In this paper, the enhancement of OCT images is carried out using various enhancement techniques to identify the method that offers improvement in the enhancement quality of the image. It presents a comparative evaluation of enhancement techniques based on the performance indices calculated from the experimental results. The results of this research work suggest the better enhancement technique suitable for OCT images depending on the various performance metrics used prominently in medical imaging.

Keywords : OCT images, Image Enhancement Metrics, Image Quality Assessment

I. INTRODUCTION

Image enhancement techniques often play a major role to improve the visual contrast nature [1] of an OCT image and that makes the extraction or segmentation of the images in an easier way. The image enhancement technique offers its interest in wide range of applications like medical image processing, video processing, seismic exploration, video surveillance etc. The main aim of this method is to change the image attributes to make it suitable for an observer or a task. In this method, single or multiple image attributes are modified to enhance the contrast nature of an image. Depending on the task, the image attributes and the method by which it is modified is selected [2].

In recent times, different image enhancement techniques are used to improve the image visual nature [3]. However, an ordinary enhancement technique does not provide satisfactory performance when it is applied with low contrast images. The unsatisfactory performance is due to the presence of higher and lower histogram components at different ends. Hence, the balancing of contrast level of image using gray level techniques is difficult [4]. It further affects the background of the image and flashes out the entire image. To eliminate all such drawbacks, histogram based equalization [5] and CLAHE [6, 7] is developed.

The OCT images, despite its recent appearance have become a clinical standard to study several diseases [8]. Hence in this

work, the OCT images are enhanced using various enhancement techniques like HE, AHE, CLAHE and MOT to determine the one that offers best result. Further, the enhancement techniques are evaluated using different performance indices AMBE, EME, EMEE, CII and TM.

Various techniques are adopted to improve the contrast nature of OCT image using image enhancement techniques. In [9], the author has adopted a self-adaptive image enhancement algorithm using histogram equalization and canny operator. This method avoids the shortcomings occurred due to HE through the canny operator, which helps in the extraction of detailed information and further it preserves the histogram in enhanced image.

In [10], the edges in near-infrared superficial vein images are blurred and further the vascular lines are not clear. Further, the low processing efficiency and high algorithm complexity is resolved using CLAHE with optimized bilinear interpolation that helps in the addition of parameter T over an interpolation function. Where the parameter 'T' helps in increasing the speed of interpolation that makes the entire process to work faster with improved image enhancement.

In [11] contrast enhancement algorithm to enhance the fundus image for clear visual perception is presented. This method uses CLAHE technique to resolve the de-noising and enhancement problems associated with color fundus image. In [12] CLAHE was used for angiogenesis OCT image enhancement. From these studies it is clear that the application of Histogram based techniques helps in improving the contrast nature of images than other techniques.

The outline of the paper is given as follows: Section 2 discusses the proposed method with different enhancement techniques. Section 3 discusses the performance evaluation metrics to determine the suitable enhancement method for OCT image enhancement. Section 4 discusses the results obtained. Section 5 concludes the paper.

II. PROPOSED METHOD

The architecture of the proposed method is given in Figure 1, where two modules are adopted to improve and test the quality of OCT image. The proposed enhancement method consists of two different modules: the former is image enhancement module and the latter is the performance indices evaluation module.

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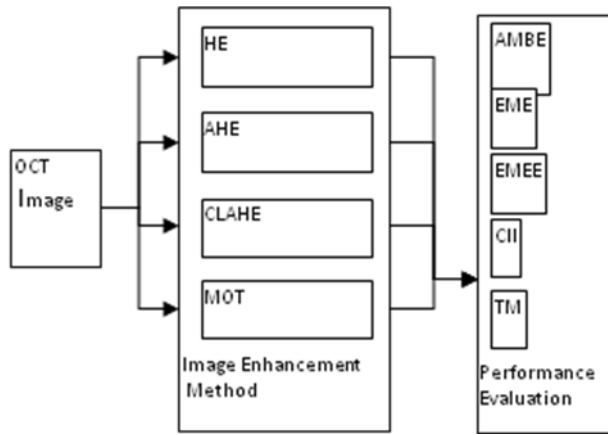


Fig. 1. Process using the Proposed Preprocessing Framework

A. Histogram Equalization (HE)

Histogram Equalization [13] is a technique in spatial domain, which is easy to implement. The HE modifies the image intensity that helps in improving the contrast level of an image. It is also defined as a transformation technique that improves the image contrast nature by proper redistribution of image gray level in a uniform way. The HE is expressed as in the following manner,

$$P(r_k) = n_k/n \tag{1}$$

where $n_k = 0, 1, 2, \dots, L-1$ and r_k are considered as the k^{th} gray level and n is defined as the total number of pixels available in an image with gray level r_k .

B. Adaptive Histogram Equalization (AHE)

AHE [13] technique transforms each pixel into a picture with a transformative function produced from the neighborhood area. It enhances an image's local contrast. The main purpose of this method is to improve both natural and medical images. But noise in homogeneous regions can be amplified. During image digitalization, this vagueness is shown by uncertain boundaries and colored values.

C. Contrast Limited Adaptive Histogram Equalization (CLAHE)

Originally, CLAHE [14] is used to improve the low-contrast medical images. The method divides the images into the associated areas and finds equalization for each area. This flattens the division of gray levels, thus increasing the visibility of the hidden features of the image. This paper equalizes the images individually in RGB color spaces. The standard CLAHE with transformed gray levels is expressed using following mathematical expression and this is expressed in terms of uniform distribution as below:

$$g = [g_{max} - g_{min}] * P(f) + g_{min} \tag{2}$$

Where g_{max} is regarded as maximum pixel value, g_{min} is regarded as the minimum pixel value, $P(f)$ is regarded as the cumulative probability distribution and g is regarded as the computed pixel value.

D. Maximization of Threshold (MOT)

Maximization of threshold method sets to increase the threshold range of lower pixels and maintains the threshold

value of higher threshold pixels. When the addition of two entropies attained its maximum by assuming the foreground and background as two different sources, the image is said to be optimally thresholded. The aspects define the entropic correlation and achieve the threshold that maximizes it. The maximization of the threshold was calculated using the two entropies which maximize the image and threshold optimally. The enhancement of OCT images used various parameters and correlation techniques to achieve the threshold which maximizes it. The algorithm is presented below,

Input: Filtered Result I_{filt}

Output: Enhanced Image I_{enh}

Procedure:

$$I_{enh}^{ij} = \begin{cases} I_{filt}^{ij} & \text{if } I_{filt}^{ij} > \frac{\max(I_{filt})}{3} \\ 0 & \text{else} \end{cases} \tag{3}$$

III. PERFORMANCE ANALYSIS

In the proposed method, the image enhancement techniques are evaluated using the following performance indices, which are given below. The quantitative performance measures used are absolute mean brightness error, measure of enhancement by entropy, measure of enhancement, contrast improvement index and Tenengrad measurement. These measures are used to measure the performance of all the image enhancement techniques and the results obtained through these measures are used for the purpose of evaluation. These measures have its own properties that have the ability to measure the details of the OCT images and help to increase the image brightness and contrast nature.

A. ABSOLUTE MEAN BRIGHTNESS ERROR (AMBE)

AMBE determines the brightness preservation [15], which is based on different brightness level between the original and enhanced image. Lower the value of AMBE implies improved preservation of image brightness. It is given by the following expression,

$$AMBE = |E(X) - E(Y)| \tag{4}$$

Where,

$E(X)$ is referred as the input image average intensity and $E(Y)$ is referred as the enhanced image average intensity.

B. Measure of Enhancement (EME)

EME [16] is defined as a measure of image enhancement method to test between the original and enhanced image. Consider an image $x(n,m)$ that is said to split into two different blocks, namely k_1 and k_2 . Here, the window $w_{k,l}(i,j)$ is maintained at the size $l_1 \times l_2$, and $\{\Phi\}$ is defined as the orthogonal transform class for enhancing the image with parameters: α , β , and λ . Using all these parameters, the EME is defined as follows:

$$EME = \max_{\Phi \in \{\Phi\}} \chi \left(\frac{1}{k_1 k_2} \sum_{l=1}^{k_2} \sum_{k=1}^{k_1} 20 \log \frac{I_{max;k,l}^w}{I_{min;k,l}^w} \right) \tag{5}$$

Where $I_{max;k,l}^w$ is the maximum value of image $X(n,m)$ within $w_{k,l}$ block and $I_{min;k,l}^w$ is the minimum value of image $X(n,m)$ within $w_{k,l}$ block. χ is regarded as sign function, where $\chi(x) = x$, or $-x$, which depends on enhancement method.



C. Measure of Enhancement by Entropy (EMEE)

EMEE [16] is defined as the image enhancement measure that uses the concept of entropy. Consider an image $x(n,m)$ that is said to split into two different blocks, namely k_1 and k_2 . Here, the window $w_{k,l}(i,j)$ is maintained at the size $l_1 \times l_2$ and hence the EMEE is defined as follows:

$$\chi(EME(\Phi)) = \left(\frac{1}{k_1 k_2} \sum_{l=1}^{k_2} \sum_{k=1}^{k_1} \frac{I_{max;k,l}^w}{I_{min;k,l}^w} \log \frac{I_{max;k,l}^w}{I_{min;k,l}^w} \right) \quad (6)$$

D. Contrast Improvement Index (CII)

CII [13] is considered as an important benchmark that helps in comparing the image enhancement technique performance. It is measured as a ratio of local contrast of enhanced image and input image, which is given by the following expression,

$$CII = A_{enhanced} / A_{original} \quad (7)$$

where,

$A_{enhanced}$ is expressed as the average local contrast level of an enhanced image with 3×3 window size and

$A_{original}$ is expressed as the average local contrast level of an input image with 3×3 window size

The increase in the value of CII shows improvement over image contrast nature.

E. Tenegrad Measurement (TM)

TM measure [13] is defined as the maximization of gradient measure. Consider an OCT image J , where the Tenegrad value is estimated using the gradient value $\Delta J(x,y)$ and sobel filter derivative is used to estimate the partial derivatives with convolution kernels j_x and j_y . Therefore the gradient magnitude of TM is expressed as:

$$T(x,y) = \sqrt{j_x \otimes J(x,y)^2 + j_y \otimes J(x,y)^2} \quad (8)$$

and hence the Tenegrad measure is estimated using the following expression:

$$TGD = \sum_x \sum_y T(x,y)^2 \quad (9)$$

Higher the value of TM, higher is the image quality and vice versa, which signifies that the image structural information is preserved.

IV. RESULTS AND DISCUSSION

The proposed method is implemented in MATLAB (R2015a) that runs on Intel (R) core (TM)-i5 2600, 3.4 GHz CPU. The implementation of OCT image enhancement techniques is carried out in MATLAB, where image processing toolbox is used to code the image enhancement techniques and quantitative performance measurement were calculated to test the given OCT input image contrast quality. To implement various image enhancement techniques, the proposed method uses OCT images for testing purpose. The image for input is shown in Figure 1 and the obtained results after the application of image enhancement techniques are displayed from Figure 2 – Figure 5. The various image enhancement techniques discussed above are used for testing the OCT image contrast quality.

After the application of image enhancement techniques, the proposed method obtains following results that are depicted in Figure 2 – Figure 5. Figure 2 shows the results of Histogram Equalization. The Figure 3 shows the results of Adaptive Histogram Equalization, Figure 4 shows the results of CLAHE and Figure 5 shows the results of Maximization of Threshold method. These figures show both input image and enhanced image, and input histogram and enhanced histogram. It is evident from these figures that the CLAHE provides highly enhanced results than the other techniques. Further, the histogram of CLAHE is improved than the other techniques

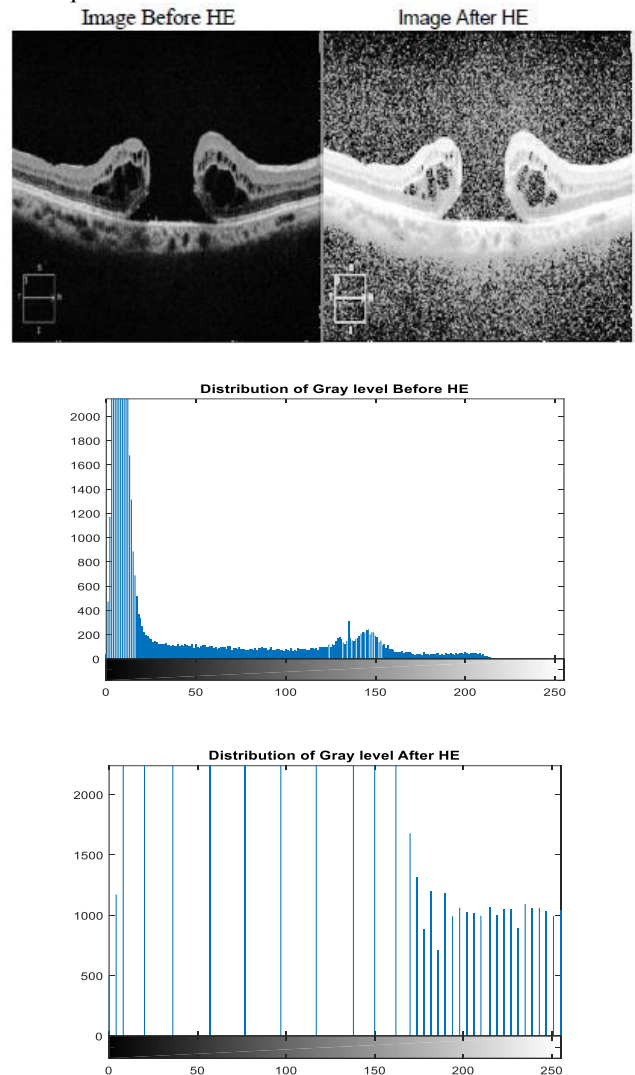


Fig. 2. Result of Histogram Equalization

The histogram image of the HE method shows a deviated output in gray level distribution as in Figure 2, which can be inferred that the image obtained HE does not provide the better output observed over OCT images.

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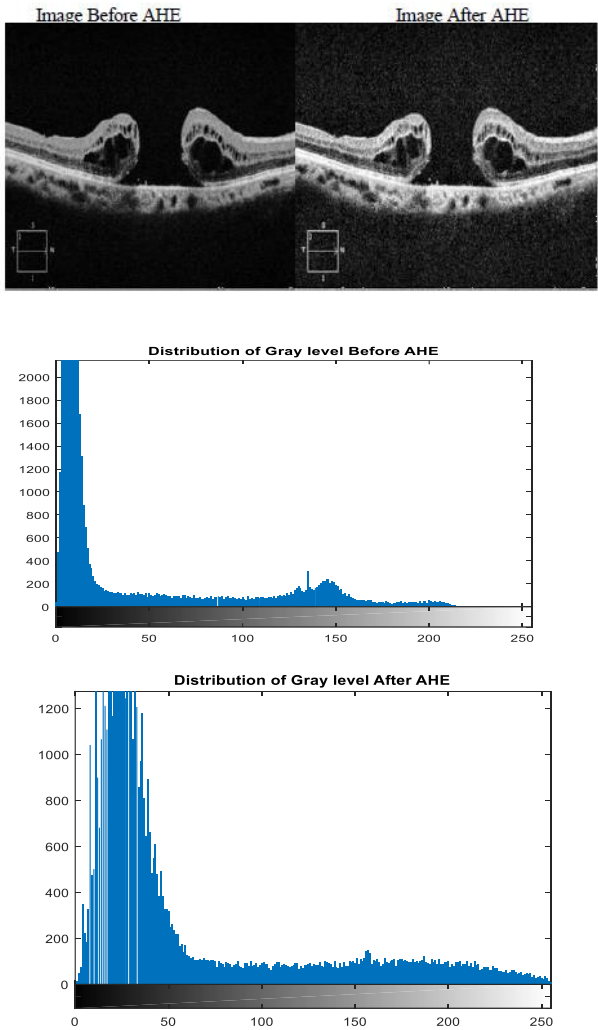


Fig. 3. Result of Adaptive Histogram Equalization

The histogram image of the AHE method shows a slight improvement in gray level distribution than the one present in Figure 2. This draws a conclusion that that the image obtained using AHE can provide the better enhancement than HE.

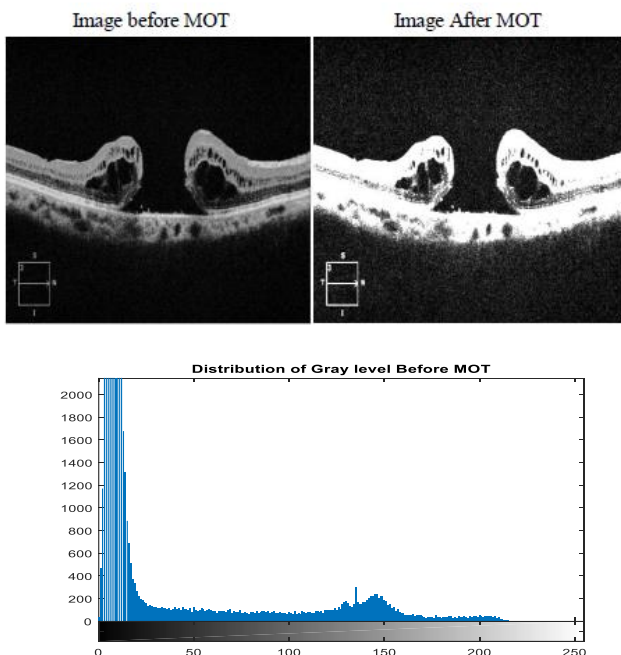


Fig. 4. Result of Maximization of Threshold

The histogram image of the MOT method shows a very lesser improvement in gray level distribution than the one present in Figure 2 and 3. This concludes that the images obtained by MOT provide the low converged output than the other techniques.

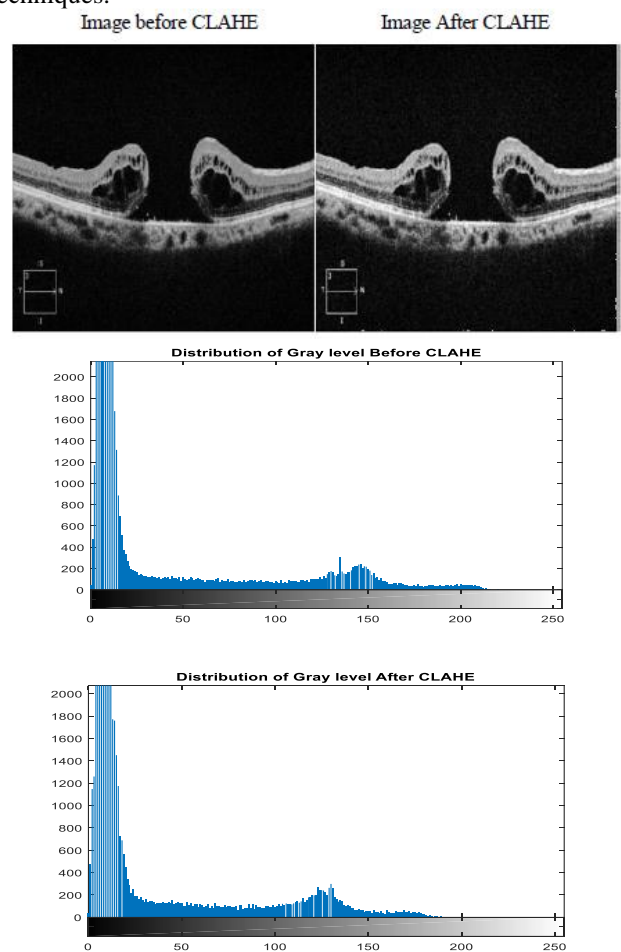


Fig. 5. Result of Contrast Limited Adaptive Histogram Equalization

The histogram image of the CLAHE method shows a highly gray level distribution output as in Figure 5 than the one present in Figure 2-4. This draws a conclusion that that the image obtained CLAHE can provide the better enhanced output observed over OCT images than the other techniques.

Table- I: Performance Analysis

Enhancement Techniques	AMBE	EME	EMEE	CII	TM
HE	94.0009	0.5439	9.6565e-04	0.0035	7.2109e+04
AHE	23.0328	0.4329	9.6565e-04	0.0047	2.2243e+04
CLAHE	4.5351	0.1373	9.6565e-04	0.0063	1.0825e+04
MOT	9.7466	0.1922	8.1538e-04	8.8593e-04	3.2126e+04

The result showing comparison of various enhancement techniques in terms of different performance metrics is given in Table 1. It is observed that the CLAHE method attains better enhanced output of OCT image than the other techniques such as HE, AHE and MOT. The CLAHE attains reduced AMBE, EME, TM and increased CII than other techniques over OCT images.

V. CONCLUSION

In this paper, the objective is to determine a better image enhancement technique to improve the contrast nature of an OCT image. The various enhancement techniques implemented are HE, AHE, CLAHE and MoT. Further presents a comparative evaluation on enhancement techniques based on the performance indices like AMBE, EME, EMEE, CII and TM. The result shows that the CLAHE method achieves improved performance in terms of reduced AMBE (4.5351), reduced EME (0.1373), increased CII (0.0063) and reduced TM (1.0825e+04). The result shows that the CLAHE method performs better on OCT images than the other techniques, which proves the efficacy of CLAHE than other histogram equalization techniques. Further the claim that the application of Histogram based techniques helps in improving the contrast nature of OCT than other techniques like thresholding is proved by the present study.

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