

Optical Microscopy Images Enhancement using YCbCr Color Space based on Nonlinear Mapping

Hind A. Majeed^{1*}, Ahlam M. Kadhim¹, Hazim G. Daway¹

¹Department of Physics, College of Science, Mustansiriyah University, 10052 Baghdad, IRAQ.

*Correspondent contact: hind.a.alrahman@uomustansiriyah.edu.iq

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ABSTRACT

Improving medical images captured by the optical microscope plays an essential role in many medical, radiological, and other applications in the medical field. In this study, the microscope image was improved based on the color conversion (Ycber) and the transformation nonlinear mapping, where the lighting component (Y) was processed based on the nonlinear transformation and fuzzy technique, and the color component was improved using (CLAHE) algorithm. The proposed algorithm was compared with several modern algorithms based on non-referenced quality measures. Analyzing the proposed results has obtained the best quality measures with high values of EN (7.0701), AG (14.6901), and MSD (55.8363).

KEYWORDS: CLAHE, lighting improvement, microscopy images enhancement, Ycber, Sigmoid mapping.

الخلاصة

يلعب تحسين الصورة الطبية التي يلتقطها المجهر الضوئي دوراً مهماً في العديد من التطبيقات الطبية والإشعاعية وغيرها في مجالات الطب. في هذه الدراسة، تم تحسين الصورة المجهرية بناءً على التحويل اللوني في فضاء (YCbCr)، حيث تمت معالجة مكون الإضاءة (Y) بناءً على التحويل غير الخطي والتقنية الضبابية، ويكون مكون اللون هو تم تحسينه باستخدام خوارزمية (CLAHE). تمت مقارنة الخوارزمية المقترحة بالعديد من الخوارزميات الحديثة بناءً على مقاييس الجودة غير المرجعية من خلال تحليل النتائج، حصلت الطريقة المقترحة على أفضل مقاييس الجودة مع قيم EN (7.0701) AG (14.6901) و MSD (55.8363).

INTRODUCTION

Digital image processing has recently become an essential technology due to the wide applications of its algorithms. Processing algorithms may either be images themselves or analyze their properties. These optimization algorithms for the medical or microscopic image play a vital role in diagnosing this image. There are different types of imaging and microscopy. Many diseases have been diagnosed through these images, but many medical images have poor contrast and fuzzy details. Proper lighting is essential in capturing necessary details in a medical image, such as accounting for shadows and highlights. In addition, the

details of the microscopic images must be improved to aid in diagnosing medical conditions. Some optimization algorithms are based on several methods, such as light recovery [1][2]. Generally, optimization techniques aim to improve the illumination of the medical image, such as the AHE adaptive histogram equation. Due to the limitations of the low dynamic range of red, green, and blue in medical imaging, they often suffer from poor contrast, irregular illumination, and low-intensity levels. It is crucial to enhance contrast and scrutinize contrast details and light intensity to study medical images effectively, as contrast is one of the essential image properties. However, AHE has inaccurate results in improving medical

images, especially when preserving the gradient [3]. An algorithm for improving medical photographs was described by Rafid Ali *et al.*, 2021 [4]; it is based on the application of fuzzy logic by the Stretch Membership Function FLSMF, where this function was employed as a membership function.

Ahlan M. (2021) [5] suggested an algorithm for improving infrared (IR) picture resolution and generating high-contrast infrared radiation. The technique uses high sub-band frequencies of LWT technology to combine optimal images with superb resolution and high contrast of thermally acquired photos.

Jobson *et al.* [6] developed the single-band Retinex (SSR) model, that is now widely accepted. Several Gaussian ambient functions from the input image are applied to this model to estimate illumination. The logarithm of the reflectance data is used to get the final image. SSR and MSR are applied separately for each of the RGB color channels. Joshi *et al.* (2008) [7] suggested a strategy for optimizing the blue, red, and green color channels to improve the image of the augmented color bed. Although the restored image remained pale, the procedure produced better results. Hind A. Majeed *et al.* [8] suggested a dialogue algorithm to enhance a medical image taken by a light microscope that has poor contrast by enhancing illumination in the color space using a first and second histogram equation based on the sigmoid, and the study then demonstrated transformation and fuzzy logic.

MATERIALS AND METHODS

The microscope image was improved based on the color conversion (YCbCr) and the transformation nonlinear mapping, where the lighting component (Y) was processed based on the nonlinear transformation and the fuzzy technique, and the color component was improved using (CLAHE) algorithm.

Lighting Improvement

The lighting was improved relying on the space (YCbCr), which gives the front shift

from the space (RGB) to the space (YCbCr) according to the relationship [9]:

$$\begin{aligned} Y &= 0.298r + 0.587g + 0.114b \\ cb &= -0.147r - 0.2880g + 0.436b \\ cr &= 0.6149r + 0.514g - 0.100b \end{aligned} \quad (1)$$

According to [10][11], a sigmoid mapping was employed to improve the image's lightness:

$$Y_i = 1 / \left(1 + \left(\sqrt{(1 - Y_n)} / Y_n \right) \right) \quad (2)$$

And:

$$Y_n = Y / 255 \quad (3)$$

Moreover, the fuzzy algorithm can be used to enhance the contrast by [4]:

$$\mu_I = \frac{Y_i - \min_I}{\max_I - \min_I} \quad (4)$$

In line with the following [5], μ_n is the crossing point:

$$\mu'_{\max} = \mu'_{av} + p \mu'_{\text{std}} \quad (5)$$

$$\mu'_{\min} = \mu'_{av} - p \mu'_{\text{std}} \quad (6)$$

The value and standard deviation of μ'_I I are, respectively, the μ'_{av} and $\text{st}\mu'_I$ d. The fuzzy logic-enhanced lightness component is shown in Figure 1(e).

Improving the Lighting Component based on CLAHE

The whole image was optimized based on (CLAHE) for each of the (RGB) components. The improvement technique using (HE) was considered one of the traditional techniques. The technique (CLAHE) is similar to the improvement of (HE), but it takes into account the division of the image into several areas and improvement through the following relationship [12]:

$$B = \frac{HW}{F} \left(1 + \frac{a}{100} (T_{\max} - 1) \right) \quad (7)$$

A is a clip factor (0 100), B is the clip limit, (HW) is the number of pixels in each section, F is the grayscale levels, and T_max is the maximum permitted slope. If a=0, the clip limit in Equation (7) is HW/F.

Reversal of Transform

Following the reverse conversion, the color information (IQ) of the images improved

using AHE was combined with the improved lightness component using fuzzy logic technology [13]:

$$\begin{bmatrix} re \\ ge \\ be \end{bmatrix} = \begin{bmatrix} 0.248 & 0.338 & 0.258 \\ 0.415 & -1.485 & -1.684 \\ 0.112 & -1.233 & 1.891 \end{bmatrix} \begin{bmatrix} y_f \\ i \\ q \end{bmatrix} \quad (8)$$

In more details, Figure 1 depicts the suggested stage, while Figure 2 shows the algorithm's steps.

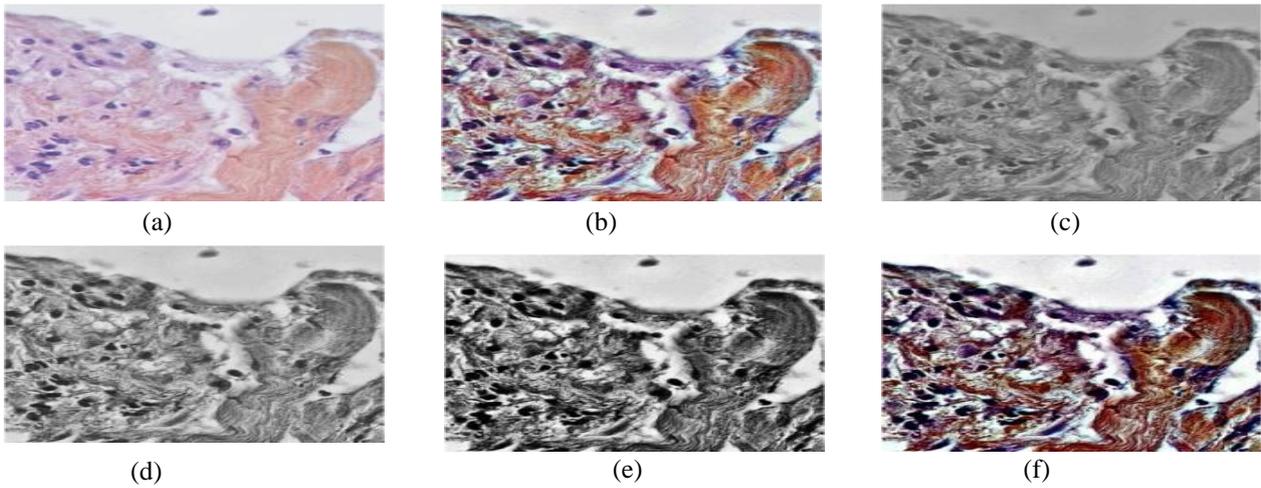


Figure 1: (a) original image,(b) image enhanced by CLAHE, (c) lightness Y component in YCbCr color space, (d) sigmoid mapping for Y-component,(e) Fuzzy enhancement after mapping and in (f) final enhancement.

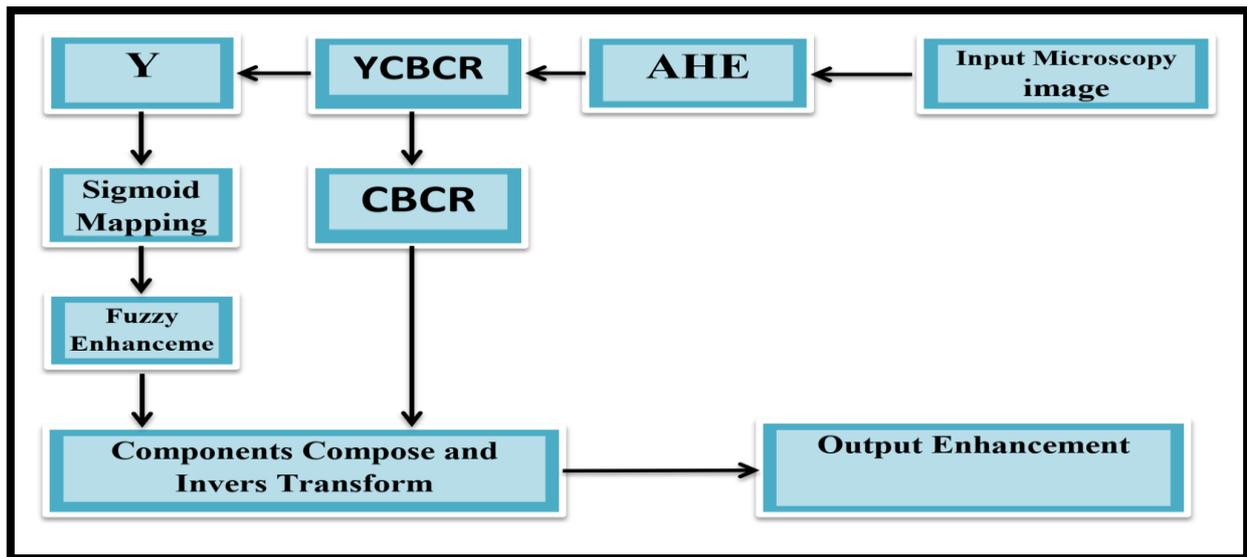


Figure 2. Steps of the suggested algorithm.

RESULT AND DISCUSSION

This study used various strategies to improve the low-contrast medical microscopy images, including AHE, FLMSF, MCHE, PCAURM, RACR, and MMSICHE and suggested (sug.).

All programs in this study used Matlab (R2020a), 12GB of RAM, and i5 and 2.5GHz processors. To ensure the effectiveness of the optimization, As models, four photographs with the names a, b, c, and d (see Figure 3)

were chosen. Entropy (En) [14], gradient mean (AG) [15], and mean standard division (MSD) [16] were three non-reference quality indicators chosen. Table 1 represents the average quality of the four selected images for all improvement methods based on non-referenced quality measures and noted from the analysis that the best results were for the proposed method followed by the methods (FLMSF).

The results were reflected in the table on the subjective observation, as shown in Figures (4, 5, and 7) that represents the images (a, b, and c) improved based on all methods, noticing the best contrast and clarity of the proposed method. Figure 6c represents the histogram distribution of the image. Analyzing the distributions showed that the suggested strategy's range was the best.

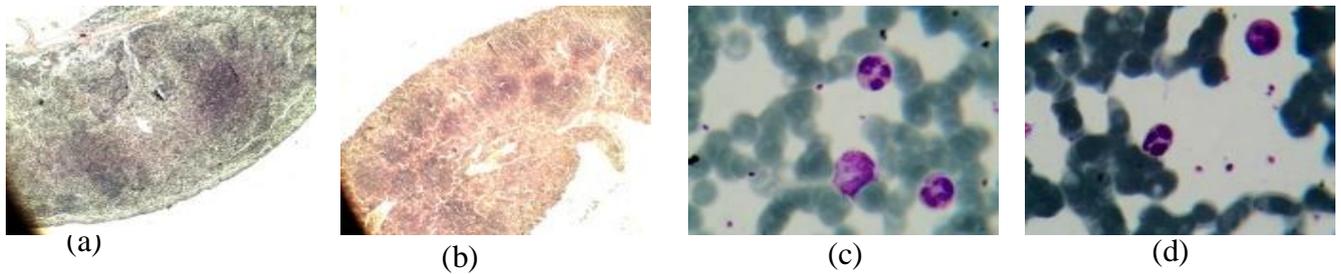


Figure 3. The study's data model for microscope images

Table 1. The quality average for nonreferenced scales.

Method	En	Ag	Msd
Sug	7.0701	<u>14.6901</u>	55.8363
AHE	7.1268	11.1217	39.2249
FLMSF	6.6190	11.4298	<u>44.6615</u>
MCHE	6.8329	<u>14.9618</u>	<u>51.9387</u>
PCAURM	<u>6.7783</u>	9.0822	35.8956
RACR	<u>7.0630</u>	11.6713	41.7607
MMSICHE	6.7297	20.3550	41.8802

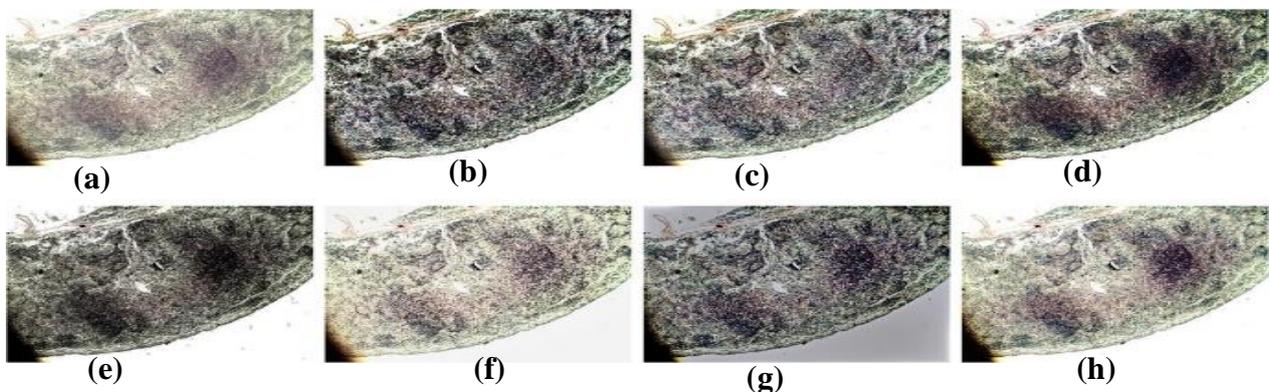


Figure 4. Microscopic image: (a) that has been enhanced using a variety of techniques from the original, (b), and (c). AHE, FLMSF, MCHC, PCAURM, f, RACR, and MMSICHE are listed from (c) to (h).

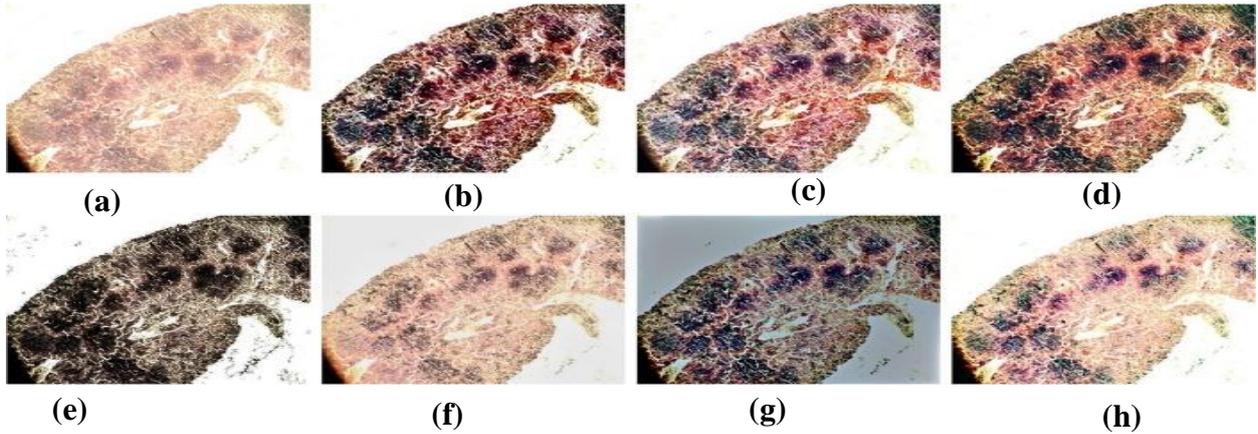


Figure 5 :a suggested microscopic image (b) enhanced using various techniques. AHE, FLMSF, MCHE, PCAURM, f, RACR, and MMSICHE are listed from (c) to (h).

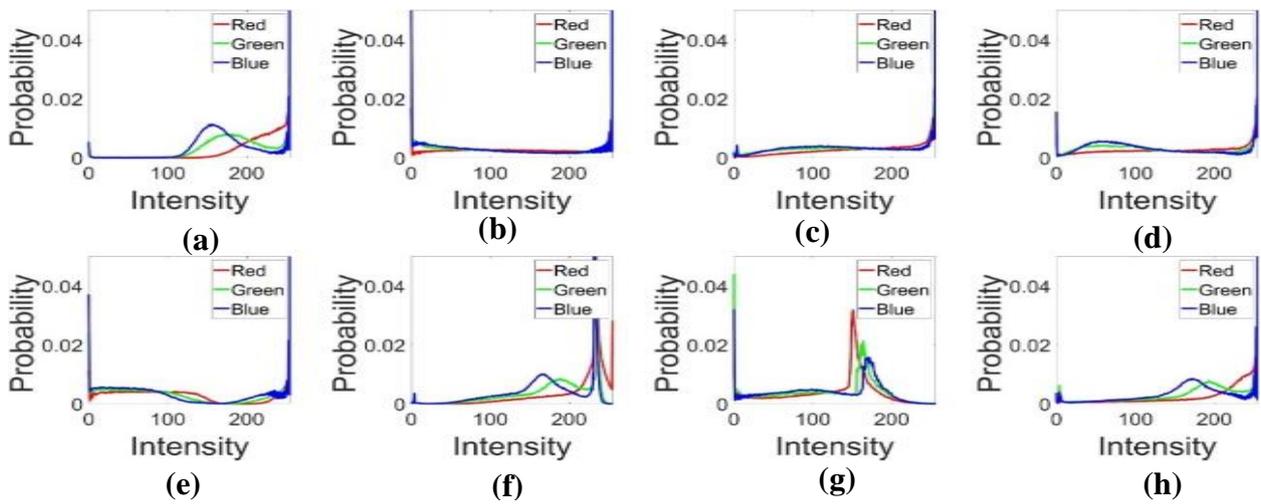


Figure 6. Histogram of the Microscopy image_b that has been enhanced using various techniques in (a) original, (b) suggestions. AHE, FLMSF, MCHE, PCAURM, f, RACR, and MMSICHE are listed from (c) to (h).

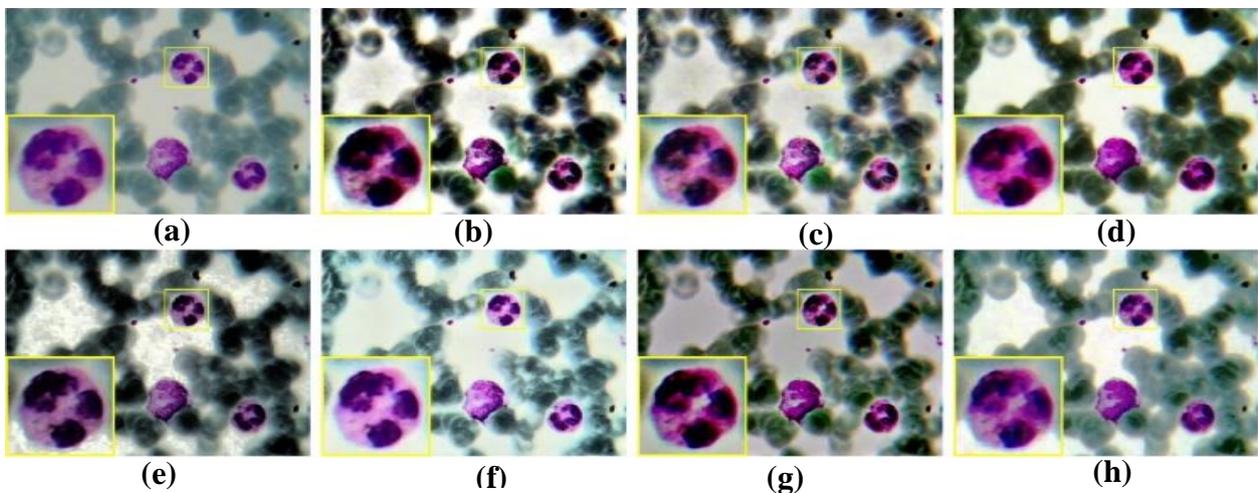


Figure 7: A microscopy image that has been enhanced using several techniques in (a) the original and (b) suggestions. AHE, FLMSF, MCHE, PCAURM, f, RACR, and MMSICHE are listed from (c) to (h).

CONCLUSIONS

The images captured by the optical microscope were improved based on an algorithm that incorporated several techniques such as color transformations YCbCr, fuzzy logic, and (CLAHE). The proposed algorithm was compared with several modern algorithms based on non-referenced quality measures. By analyzing the results, the proposed method obtained the best quality measures with high EN (7.0701), AG (14.6901), and MSD (55.8363) values.

Disclosure and Conflict of Interest: The authors declare that they have no conflicts of interest.

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