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Enhancement of Microscopy Images by Using a Hybrid Technique Based on Adaptive Histogram Equalisation and Fuzzy Logic

Hind A. majeed[1] **Ahlam M. Kadhim**[1]* **Hazim G. Daway**[1]

[1]*Department of physics, College of Science, Mustansiriyah University, Baghdad, Iraq*
* Corresponding author's Email: ahlammajead@uomustansiriyah.edu.iq

Abstract: The enhancement of colour medical microscopy images plays an important role in biological fields. Colour medical microscopy images have the lack of contrast and lighting. In this paper, a robust algorithm for enhancing microscopy images was proposed. In the proposed method, the image was first improved by using Contrast-Limited Adaptive Histogram Equalisation (CLAHE). Then, the luminance channel in the colour space was enhanced on the basis of sigmoid transformation and fuzzy logic. Data containing 50 medical microscopy image forms were studied, and the suggested method for enhancement was compared with several other methods, such as principal component analysis using the reflection model, fuzzy logic by stretch membership function, CLAHE, modified colour histogram equalization, contrast-enhancement based on median–mean based sub image-clipped histogram equalization and retinex method by colour restoration. The collected results illustrated that the suggested method gets excellent quality averages in terms of entropy value (7.96), average gradient (14.57) and mean of standard division (62.80).

Keywords: CLAHE, Microscope image enhancement, (YIQ) color space, Sigmoid mapping.

1. Introduction

Image improvement is one of the branches of image processing it is involved in various application such as object detection [1], recognition[2], dehazing images[3], and medical optical microscopy images [4, 5], which is a preliminary stage for distinction and detection [6, 7]. Therefore, this study aims to improve the images captured through optical microscopy. Numerous previous studies have focused on the improvement of microscopy images. Timothy et al. [8] presented an algorithm to improve optical microscopy images. Artificial intelligence techniques relying on a mathematical optimisation model based on a similarity metric were used in this method. A good improvement in the contrast of images was found. Ali et al. [5] introduced an algorithm to enhance medical images. This algorithm was based on the use of the Fuzzy Logic depending on a Membership using Stretch Function (FLMSF) as a membership function. This algorithm provided good contrast enhancement to three types of magnetic resonance, microscopy and X-ray images. An algorithm using the micro_fem orthogonal technique to improve the microscopy images of bone samples was also suggested. This algorithm included several main steps. In the first step, the work area was determined. In the second step, the area was optimised by using light technology. In the third step, several characteristics were improved. In the fourth step, the micro-fem orthogonal technique was used. One of the weaknesses of this method is it works directly on the color component and sometimes a color error occurs.

Abd-Alameer et al. [6] presented a nonreference scale for measuring microscopy images. This scale depended on calculating the value of the wavelet transform, which was converted by using the wavelet. Here, two sources of light, namely, yellow tungsten and a lighting emission diode, were used. By analysing their results, they obtained a nonreference scale and found a high correlation with subjective measurements.

Qingtao et al. [9] suggested improving the perceptual contrast of images based on retinex by using luminance adjustment. Retinex theory was used to analyse the image into layers of lighting and reflection, and luminance was adopted and adapted to address the lighting layer by using adaptive filtering to remove aura effects. Finally, the contrast of multiscalar retinex result was enhanced. The experimental results showed that method successfully improved the contrast of the images while retaining textures in shaded areas.

N. Singh and A. Bhandari [10] proposed the Principal Component Analysis Using Reflection Model (PCAURM). In this method, RGB colour input images were selected first to correct any kind of colour distortion then converted into colour domain HVS. The brightness coefficient of component V was calculated by applying the multiband technique. The image brightness enhancement system used the Fechner principle, which adaptively regulated the optimisation function parameters. Furthermore, it was framed by PCA by using the image merging method to calculate the attached features of the two images. Finally, the model applied the adaptive graph technique with finite variance CLAHE to enhance the general variance relative to the other extreme. But this method has limited retrieval of color information.

W. Hsu and C. Chou [11] proposed a method for image enhancement that included hue preservation using Modified Color Histogram Equalization (MCHE) this method is Compared with the image equalisation of each RGB colour space by using the Histogram equalisation. This method yielded good results with higher accuracy in terms of mean square error and peak signal-to-noise ratio when applied on retina and prostate cancer images. But sometimes there are errors in the colors.

F Sun, and L. Bo [12] proposed combining the enhanced particle swarm optimisation method with the single-band retinex algorithm, wherein the original RGB image was converted into the HSL-colour domain and each pixel in the image with poor light was classified individually. The kernel values of the pixels were based on different filter templates to complete image optimisation and solve the problematic effect and chromatic malformation of the image as a result of a real-time operation of the spatial filter of a retinex algorithm. Their results indicated showed high efficiency in adjusting contrast and brightness and restoring colour.

M. Ahlam and H. Basaad [13] proposed an algorithm to enhance infrared (IR) image resolution and produce high-contrast IR images based on Lifting Wavelet Transform (LWT). The algorithm was based on combining the high sub-band frequencies of LWT to obtain enhanced thermally captured images with good resolution and high contrast. And then they adopted Discrete Wavelet Transform (DWT) based on the traditional wavelet to produce IR images with higher quality than the original images. The technique used DWT and IDWT coefficients to analyse IR images. This technique has been successful in the field of the day and night vision of thermal cameras [14].

S. Kuldeep, and R. Kapoor [15] introduced a contrast-enhancement algorithm based on Median Mean based Sub Image Clipped Histogram Equalisation (MMSICHE). This method involves three steps. In the first step, the mean and average lightness values of the image are calculated. In the second step, the graph was clipped with a fixed boundary and set as the average occupied density. The cut-off histogram was firstly divided on the basis of the mean intensity then divided into four subimages on the basis of the individual average intensity. Subsequently, histogram equalisation was performed on each subimage. Daway et al. [16] suggested an algorithm based on the contrast enhancement technique by using the Retinex Algorithm by Colour Restoration (RACR) and applied this method in X-ray image enhancement. Their results illustraed that method succeeded in increasing the contrast of X-ray images.

In this study, the aim was to improve the optical microscope images relying on Hybrid Technique Based on Adaptive Histogram Equalisation and Fuzzy Logic using YIQ color space, this algorithm allows to improve the brightness and contrast of microscope image while preserving the color information , We clearly reflect this behavior in the results of the study.

2. Proposed method

The proposed method for improving microscopy images is based on merging several techniques, AHE and increasing contrast by using the sigmoid function and the fuzzy technique. The chromatic component (IQ) in a YIQ colour space is processed by using the AHE method, whereas the lightness component (Y) is improved by using the sigmoid function and fuzzy logic. The most important basic steps of the proposed method are as follows:

2.1 Enhancement based on AHE

AHE is one of the most important ways to improve contrast. Firstly, the image is divided into several regions. Secondly, a segment of the cut image is calculated from the graph; then, in a distinctive and professional manner, each histogram is distributed provided that the height does not exceed the segment limit. Through this division, we obtain a term that can be described as follows [17]:

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

B represent the clip limit, (HW) is the number of pixels in each region, F being the grayscales levels, a is a clip factor $(0 - 100)$ and T_{max} is the maximum allowable slope. In the Eq. (1), if $a = 0$, where $clip\ limit = HW/F$. However, T_{max} should be set to 4 for still images. AHE-based enhancement is illustrated in Fig. 1(b).

2.2 Constant enhancement

After the enhancement of all colour compounds (RGB) by using AHE, the lighting component is extracted and improved on the basis of the sigmoid function and fuzzy logic. Here, the image is converted from the basic space into the YIQ space depending on [18]:

$$\begin{bmatrix} y \\ i \\ q \end{bmatrix} = \begin{bmatrix} 2.990 & 0.587 & 0.114 \\ 0.596 & -0.270 & -0.322 \\ 0.211 & -0.211 & 0.312 \end{bmatrix} \begin{bmatrix} r \\ g \\ b \end{bmatrix} \qquad (2)$$

$$Y = 2.990r + 0.587g + 0.114b \qquad (3)$$

The sigmoid function is used to improve a contrast of the image as given by [4]:

$$\mathrm{Ye} = 1/\left(1 + \left(\sqrt{(1 - \mathrm{Y})/\mathrm{Y}}\right)\right) \qquad (4)$$

Fig. 1(c) represents the lightness component (Y), and Fig. 1(d) illustrates the enhancement of this component by using sigmoid mapping.

After the lighting component Ye is improved, it is improved again by using the fuzzy logic technique [5]:

$$max\ \_I = av + \mathrm{p}(std\_\mathrm{Ye}) \qquad (5)$$

$$min\ \_I = av - \mathrm{p}(std\_\mathrm{Ye}) \qquad (6)$$

av and std_Ye represent the mean value and standard deviation respectively. p is the constant (the best value $p = 2.5$), the membership function is given by [5]

$$\mu_I = \frac{\mathrm{Ye} - min\ \_I}{max\ \_I - min\ \_I}. \qquad (7)$$

μ_n is the crossover point in accordance with the following [19]:

$$\mu_I{}' = f_n(\mu_I) = f_n(f_{n-1}(\mu_I)) \quad , \quad n = 1,2,3,\ldots, \qquad (8)$$

where $f_n(\mu_I)$ is the successive applications given by [20]:

$$\mu_I{}' = \begin{cases} 2\mu_I{}^2 & 0 \le \mu_I < 0.5 \\ 1 - 2(1 - \mu_i)^2 & 0.5 \le \mu_i \le 1 \end{cases} \qquad (9)$$

Finally, the de-fuzzification operation for the contrast improved image is given by:

$$c' = g^{-1}(\mu_I) \qquad (10)$$

This is done by [5]:

$$y\_f = \mu'_I(\mu'_{max} - \mu'_{min}) - \mu'_{min} \qquad (11)$$

μ'_{min} and μ'_{max} are inverse mapping of each channels RGB are described by [5]

$$\mu'_{max} = \mu'_{av} + \mathrm{p}\,\mu'_{std} \qquad (12)$$

$$\mu'_{min} = \mu'_{av} - \mathrm{p}\,\mu'_{std} \qquad (13)$$

The μ'_{av} and μ'_{std} are the value and standard deviation of μ'_I, respectively. Fig. 1(e) represents the lightness component enhanced by using fuzzy logic.

2.3 Inverse transformation:

It is combined with the enhanced lightness component using fuzzy logic technology to preserve the colour information (IQ) of the images enhanced with AHE in accordance with the reverse conversion as follows [18]:

$$\begin{bmatrix} re \\ ge \\ be \end{bmatrix} = \begin{bmatrix} 0.248 & 0.338 & 0.258 \\ 0.415 & -1.485 & -1.684 \\ 0.112 & -1.233 & 1.891 \end{bmatrix} \begin{bmatrix} y\_f \\ i \\ q \end{bmatrix} \qquad (14)$$

Fig. 1(f) shows the final enhancement in accordance with the suggested algorithm. Fig. 2 illustrates the steps of this algorithm.

3. Result and discussion

In this study, low-contrast medical microscopy images were enhanced by using many methods, such as AHE, FLMSF, MCHE, PCAURM, RACR,

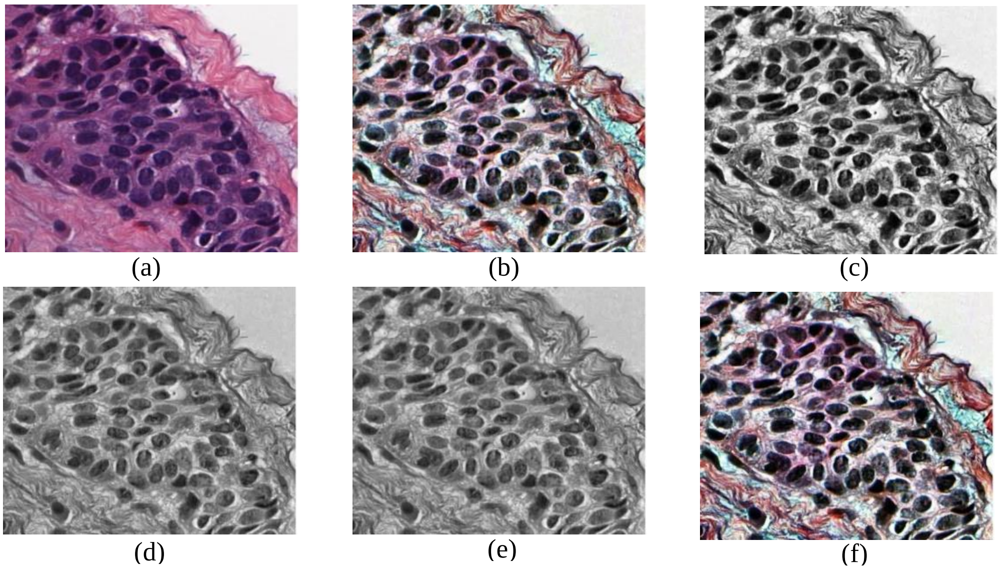

Figure. 1 Steps of the suggested algorithm for the: (a) original image, (b) AHE, (c) Y component in the YIQ colour space, (d) Y is enhanced through sigmoid mapping, (e) image, (d) enhanced by fuzzy logic, and (f) final enhancement

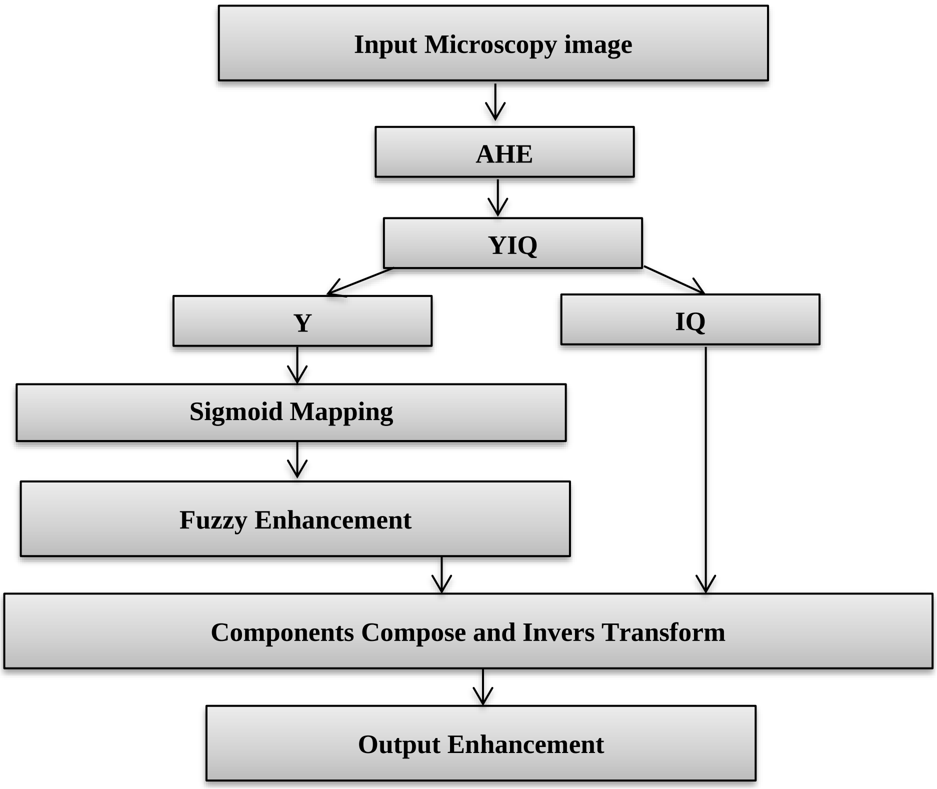

Figure. 2 Steps of the suggested algorithm

MMSICHE and Suggested (sug.). As illustrated in Fig. 3, 50 microscopy JPG-type images from [21] with the size of 512 × 512 type were used. Then, Matlab (R2020a), i5 RAM 12 GB and a 2.5 GHz processor were applied to process all programs. Four images with the labels a, b, c and d (see Figure 4) were selected as the models to determine the efficiency of the improvement. Three non-reference quality measures were adopted, namely Entropy (En) [22], Average Gradient (AG) [23] and Mean of Standard Division (MSD) [24]. Table 1 shows the rate of non reference quality measures for the 50 images by using several improvement methods. We note that the proposed method had the best quality standards, followed by PCAURM and AHE, because the images improved by the proposed algorithm obtained an increase in contrast, retrieved a lot of color information, and obtained the highest

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values for all non-reference scales. The same table is illustrated in Fig. 5 in the form of a 3D bar graph. Fig. 6 shows an area enlarged for a selected region within the image with label a. We notice that under the proposed method, the details in that region had increased and it got a high contrast. The proposed method, followed by the AHE and PCAURM methods, had the best performance, whereas the MMSICHE method was the worst method. Fig. 7 shows image b, which had been improved by using several methods. The figure corresponded to the distribution of the histogram (Fig. 8) for the images. We note that the suggested method, followed by the (AHE) method, had the best distribution of the histogram that included the widest ranges for red, green and blue channels.

Table 2 shows a selected image with labels a, b, c and d from the data. We note the same behaviour in Table 1, i.e. the best method was the suggested method followed by the PCAURM and AHE methods.

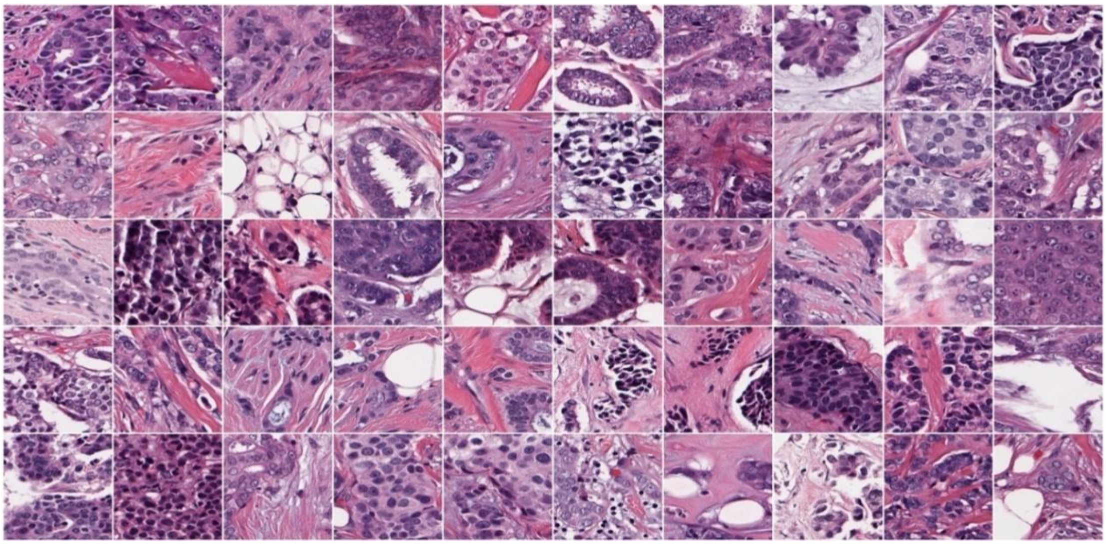
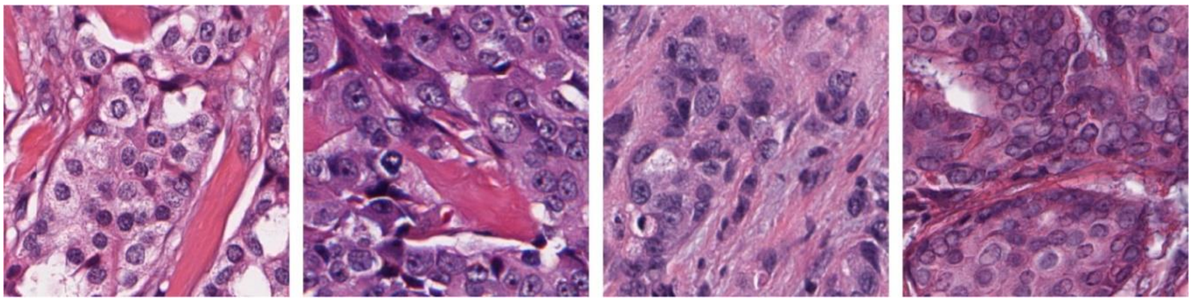


Figure. 3 Data model for microscopy images used in this study (50 images)



(a) (b) (c) (d)

Figure. 4 Four images selected from the data model: (a) Image a, (b) Image b, (c) Image c, and (d) Image d

Table 1. Quality average for nonreferenced scales

method	EN	AG	MSD
Sug.	**7.96**	**14.57**	**62.80**
AHE[17]	7.94	13.92	59.94
FLMSF[5]	7.60	12.15	56.83
MCHE[11]	7.67	13.61	59.75
PCAURM[10]	7.67	10.81	51.06
RACR[16]	7.37	12.82	56.85
MMSICHE[15]	7.65	9.17	42.82

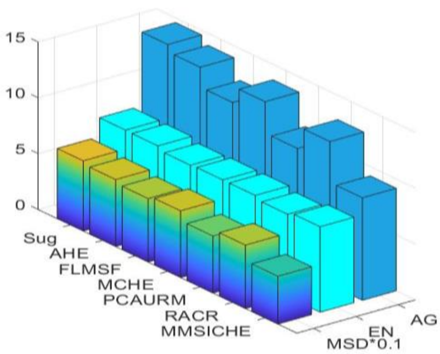


Figure. 5 3D bar representation for Table 1

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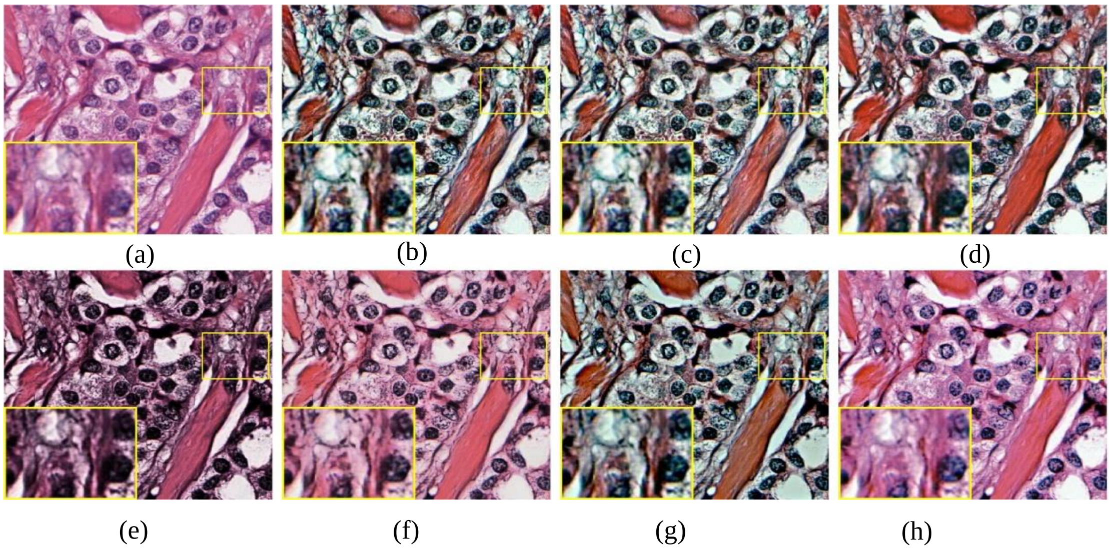

Figure. 6 Microscopy image_a with enlarge area which has been improved using several methods in (a) Orginal, (b) sug, (c) AHE, (d) FLMSF, (e) MCHE ,(f) PCAURM , (g) RACR, and (h) MMSICHE

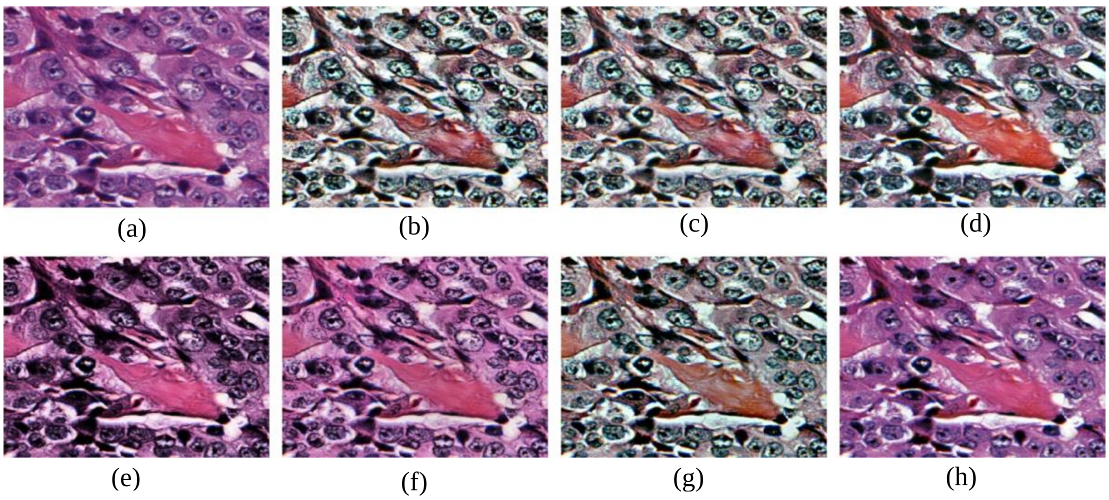

Figure. 7 Microscopy image_b which has been improved using several methods in (a) Orginal, (b) sug, (c) AHE, (d) FLMSF, (e) MCHE ,(f) PCAURM, (g) RACR, and (h) MMSICHE

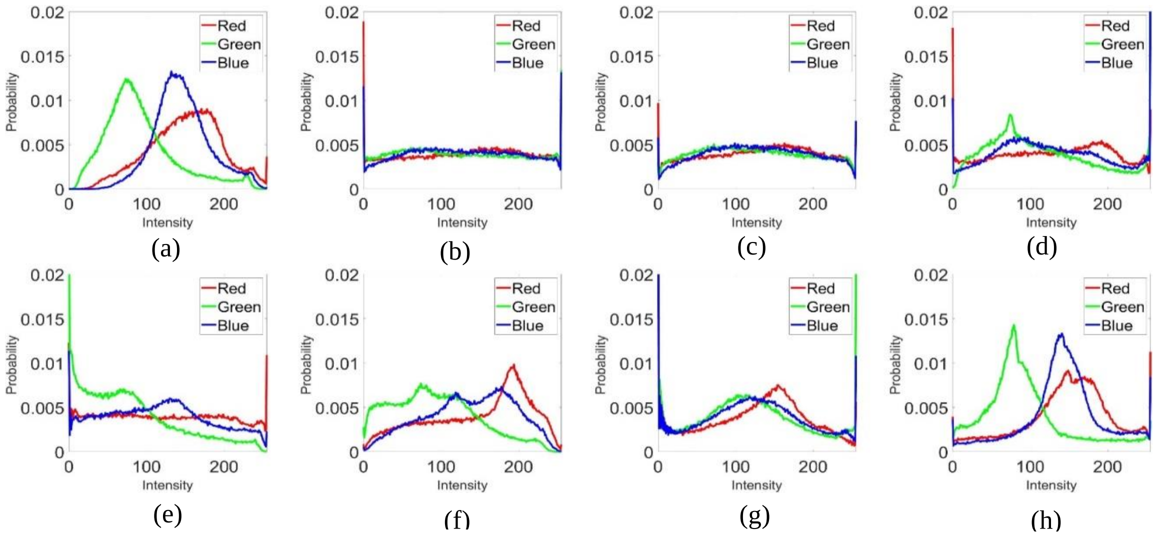

Figure. 8 Histogranm of the Microscopy image_b which has been improved using several methods in (a) Orginal, (b) sug, (c) AHE, (d) FLMSF, (e) MCHE, (f) PCAURM, (g) RACR, and (h) MMSICHE

Table 2. Quality average for nonreferenced scales for the images with label (a, b, c and d)

Image _a				Image _b			
Method	**EN**	**AG**	**MSD**	**Method**	**EN**	**AG**	**MSD**
Sug.	7.98	13.76	65.10	**Sug.**	7.99	15.71	63.50
AHE	7.98	13.06	61.38	**AHE**	7.95	14.63	59.06
FLMSF	7.70	11.75	57.77	**FLMSF**	7.56	13.09	57.70
MCHE	7.67	13.05	63.33	**MCHE**	7.69	14.65	61.48
PCAURM	7.88	11.79	55.91	**PCAURM**	7.69	9.94	47.66
RACR	7.51	12.54	59.24	**RACR**	7.28	14.10	59.16
MMSICHE	7.76	8.50	42.52	**MMSICHE**	7.57	9.32	40.83
Image _c				**Image _d**			
Method	**EN**	**AG**	**MSD**	**Method**	**EN**	**AG**	**MSD**
Sug.	7.99	16.64	65.43	**Sug.**	7.99	15.15	65.31
AHE	7.97	15.53	60.58	**AHE**	7.98	14.67	63.04
FLMSF	7.45	14.18	57.49	**FLMSF**	7.73	13.90	61.97
MCHE	7.66	15.09	63.01	**MCHE**	7.68	15.07	66.26
PCAURM	7.86	14.36	58.73	**PCAURM**	7.77	11.86	54.14
RACR	7.57	15.73	59.53	**RACR**	7.50	14.33	61.48
MMSICHE	7.61	9.91	40.02	**MMSICHE**	7.77	10.20	44.97

4. Conclusion

The main objective of this study to improve microscopy medical images with little variance by adopting the non reference quality measures AHE, FLMSF, MCHE, PCAURM, RACR and MMSICHE. The results showed that the proposed algorithm successfully improved the medical images compared with other methods and had high values of EN (7.96), AG (14.57) and MSD (62.80). In the future, the sugusted algorithm can be used to enhance color images with nonunform lightness levels.

Appendix

The code for the proposed method can be downloaded by the link: https://drive.google.com/file/d/1-mjCEh6IV22GrgNPSKv4EWu9_VM0_aqa/view?usp=sharing

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Hazim G. Daway has contributed to the design and implementation of the research by using Matlab. Hind A. majeed and Ahlam M. Kadhim have supervised the written paper and providing the necessary data. All authors approved the final version.

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