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Enhancement of Very Low Light Images Using the YIQ Space Based on the CLAHE and Sigmoid Mapping with High Colour Restoration

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ABSTRACT

Low-light image enhancement is a branch of digital image processing and is of great importance in many applications: aerial images, tracking, medical imaging and other applications. Therefore, this study aims to enhance the very low light images by relying on contrast limited adaptive histogram equalisation (CLAHE) with non-leaner sigmoid mapping based on YIQ colour space. Thus, the lighting component (Y) has been enhanced using CLAHE and sigmoid mapping, and the colour compound (IQ) has been treated via colour restoration. Color conversions are used to reduce any color error after enhancement, as the lighting component can be processed using CLAHE from the lighting component only. Two quality measures, namely, perception-based image quality evaluator (PIQE) and entropy (EN) were adopted to determine the efficiency of improvement. The proposed method was compared with several other methods, and the results were analysed. The findings indicate that the proposed method increased the lighting and restored the colours; it obtained the highest values for PIQE (34.598) and EN (7.025).

1. INTRODUCTION

Improving low-light images plays an important role in many image processing applications, the most important of which are night images, medical images [1, 2], scenes with irregular lighting, and images taken at high depths. Therefore, we sought to improve low-light images. The availability of technology and tools that simplify image alteration has increased the use of digital images in recent years. Users can manually regulate how much light enters the lens by manually altering the lens size whilst using conventional cameras. Digital cameras only need a basic understanding of the user and how they operate in the direction of light. Light should be transformed into electrical charges and the image into a series of zeros and ones to represent all coloured dots in the image [3]. Marine life and fish, breath-taking scenery and mystery shipwrecks are amongst the unique attractions that the environment offers. In addition to underwater images, underwater imaging has generated significant interest in numerous fields of technology and science research, including the examination of underwater cables and infrastructure, the detection of man-made objects and the operation of underwater vehicles, marine biology research and archaeology [4]. Until recently, image enhancement has been used in various fields of science and engineering, including computer vision, biomedicine, astrophotography and atmospheric sciences. Image improvement methods point to a convincing outcome because these techniques not only satisfy the need for increased outputs that are visually appealing but also bring back the consistency and sturdiness of outdoor viewing. Different techniques have been developed to lessen the distortion caused by the low lighting. With the growth of social media platforms, such as Facebook and YouTube, capturing photos or videos of people's daily lives and posting them online have become common. One of the easiest methods for enhancing images, histogram equalisation (HE) [5], increases dynamic range but has issues with over-enhancement; many researchers have developed this technique [6, 7]. In the study, Zhou et al [8] introduced parallel nonlinear adaptive enhancement (PNAE) techniques to improve colour images with different lighting. Firstly, they used intensity transform via local neighbourhood depending on the intensity mapping function by Taylor transform, one of the disadvantages of this method is that it does not provide good contrast improvement at low lighting levels. This method enhanced the contrast, but not the areas with uniform lighting. Another important traditional method is contrast limited adaptive histogram equalisation (CLAHE) [9]. In this algorithm, the variance augmentation methods address the drawbacks of traditional graph equalisation. CLAHE was created initially for medical imaging; it has the ability to enhance low-contrast images, such as those from gateway films. Many studies have developed the CLAHE method in improving the image, such as the researches [10, 11]. In the study [12], Wang et al. suggested an optimisation approach using nature conservation objectively, where the lightness order error was measured.

Secondly, the image is examined using a bright-pass filter to separate it into reflection and illumination, which define the details and character of the image, respectively. Thirdly, they suggested using a two-log transform to map illumination, thereby striking a balance between naturalness and detail.

Ancuti et al [4] suggested a workable method for restoring underwater images that had been damaged by scattering and weak absorption. Hardware or technical understanding of underwater conditions or scene structure is unnecessary for a single image phrase. It is based on combining two images made from a white-balanced copy of the original image's degraded counterpart. The verification demonstrates that our technique enhances the accuracy of numerous image processing applications, including picture segmentation and keypoint matching; it is mostly independent of camera settings. In the study [13], the contrast enhancement approach (CEA), used to improve contrast for dark photographs with unpredictable lighting without harming the details in bright parts, was suggested by an algorithm. A solution that works with the 'YCbCr' model was suggested given that the luminance part 'Y' was used individually with this colour model. Then, the recently created sigmoid function was used to optimise the brightness 'Y' portion of the image, one of the weaknesses of this method is that it does not provide good color improvement at low lighting levels. Daway et al [3] suggested using logic methods to create a Fuzzy Logic-Based Sigmoidal Function (FLSMF) to boost the colour images' contrast and lighting. The colour compounds remained unchanged when the FLBSMF algorithm was applied to the lighting component using only the YIQ colour space. The suggested technique has been contrasted with various algorithms, including fuzzy logic, the optimisation of which utilises a modification of the membership function based on quadratic operations, it is considered a good algorithm that improves lighting and contrast in a balanced manner. Ren et al [14] suggested the Retinex low-order modulator model (LR3M) approach, which is the first to pre-inject a low-order material into the Retinex breakdown process to suppress noise in the reflection map. This technique benefits from simple sectional illumination and successive suppression of reflection noise, where LR3M is used to improve image in low light, Despite the high color recovery in this method, it smooth the image, which reduces contrast and increases blur.

The proposed method produces better-quality noise reduction and optimisation results than more recent techniques for various pictures and movies. Singh et al [15] suggested a fresh reflection model and principal component analysis-based low-light image enhancement (LIME) technique. Based on the reflection model, the suggested algorithm operates adaptively with dark pictures. Then, to increase the overall contrast, a CLAHE finite contrast adaptive graph equalisation model is utilised in conjunction with an image brightness enhancement strategy based on the Fechner principle. The suggested strategy produces superior outcomes to previous methods for subjective and objective evaluations. Abraham et al [16] suggested an algorithm to enhance very low lightness images depending by using modified brightness based on sigmoid function (MBSF). This algorithm used brightness low lightness areas by YIQ colour space, including sigmoid mapping for lightness component.

2. SUGGESTED ALGORITHM

The proposed algorithm depends on enhancing the images captured at very low light levels in two main steps. The first step is colour restoration that uses the CLAHE algorithm, and the second step is contrast enhancement of the lighting component using sigmoid mapping that uses the YIQ colour space.

2.1 Colour restoration

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

Figure 1. In (a) original image, (b) lightness component, (c) lightness component enhanced by CLAHE and (d) final colour restoration

Colour distortion occurs because the image was captured at low lighting levels. Therefore, colour retrieval is an essential stage of enhancement. The proposed colour restoration depends on the implementation of the CLAHE algorithm. The lighting component for colour image c_i is calculated according to the following:

$$I = \max(r, g, b) \tag{1}$$

where, i = red (r), green (g) and blue (b), Then, an improvement was made to use CLHE as follows [9]:

$$I_e = CLAHE(I) \tag{2}$$

The colour restoration coefficient is calculated by:

$$R = I_e/I \tag{3}$$

The image colour is restarted by the following:

$$CR_i\text{=}Rc_i \tag{4}$$

Figure 1 represents the stages of colour retrieval, where the degree of colour accuracy is observed after retrieval.

2.2 Contrast enhancement by YIQ colour space

The contrast of the lighting component should be increased while preserving the colour retrieval. For this purpose, the YIQ colour transformation is used, and the lighting component is processed only using sigmoid mapping. The recovered image is initially converted from space RGB to YIQ colour space using the following equation [17]:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 2.99 & 0.587 & 0.114 \\ 0.596 & -0.270 & -0.322 \\ 0.211 & -0.211 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{5}$$

Subsequently, the lighting component (Y) is extracted and converted using the following function [3]:

$$\text{Ys} = \frac{1}{(1-(\frac{\sqrt{1-\text{Yn}}}{\text{Yn}}))} \tag{6}$$

Yn is the normalised lightness component Y. One of the characteristics of this function is to increase the intensity at low lighting levels and maintain it at medium lighting levels. However, at high lighting levels, this function works to reduce the intensity levels, thereby providing a homogeneous improvement of lighting and contrast, as shown in Figure 2.

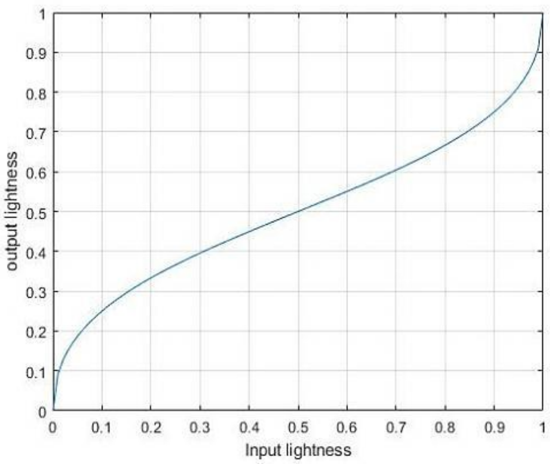


Figure 2. Sigmoid function transform [3]

Then, the inverse transformation is applied by [18]:

$$\begin{bmatrix} Re \\ Ge \\ Be \end{bmatrix} = \begin{bmatrix} 0.248 & 0.338 & 0.258 \\ 0.415 & -1.485 & -1.684 \\ 0.112 & -1.233 & 1.891 \end{bmatrix} \begin{bmatrix} Ys \\ I \\ Q \end{bmatrix} \tag{7}$$

Figure 3 represents the stages of contrast improvement depending on the colour space, where we notice an increase in contrast whilst preserving the colour compounds. Figure 4 represents a diagram of the most important basic steps of the proposed algorithm.

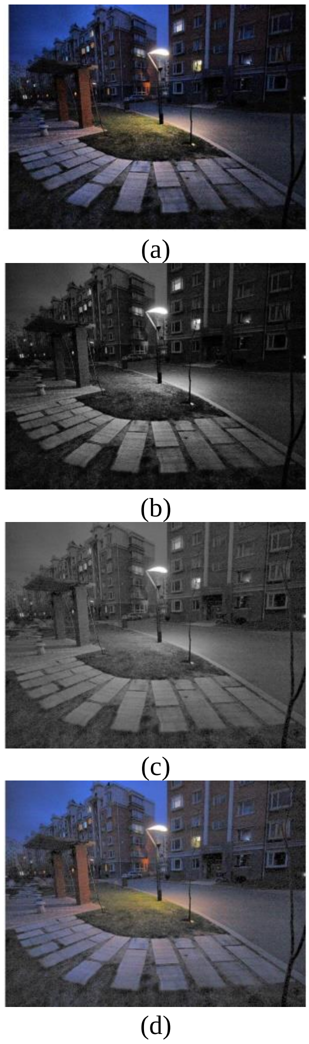


Figure 3. In (a) colour restoration, (b) lightness component, (c) sigmoid mapping for the lightness component, and (d) final enhancement

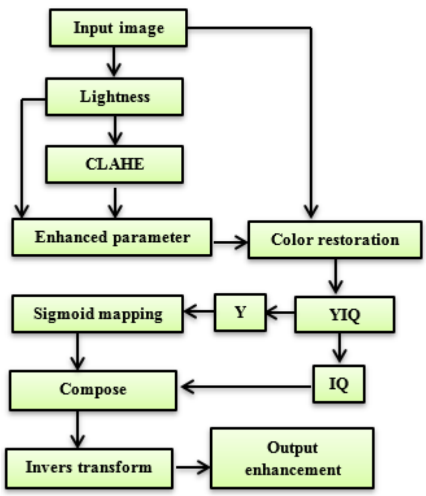


Figure 4. Steps of the suggested algorithm

3. RESULTS AND DISCUSSION

In this study, the low light images are enhanced using

LIME-data [18] that consist of (10) low light images within JPG format, as shown in Figure 5 and we selected four images models for calculating quality (see Figure 6). Matlab R2020a program is used to perform all enhancement algorithms. The proposed algorithm is compared with several methods (MBSF, CEA, FLSMF, AHE, PNAE and LR3M) using quality assessment of EN [19, 20] and PIQE [21]. Table 1 presents the average quality of all methods that were obtained; it shows the best results for the suggested method, followed by the method AHE, the same behavior is reflected in Table 2 for the four enhanced images. Figures 7 and 8 represent the images (1 & 4) have been enhanced using various methods. A large area has been selected to show the quality of enhancement. These figures indicate that the proposed method increased the brightness and contrast whilst preserving colour details. Figure 9 illustrates image (3) that has been selected to study the histograms for all enhancement methods, from Figure 10 we can see that the best distribution ranges are good for the suggested method.

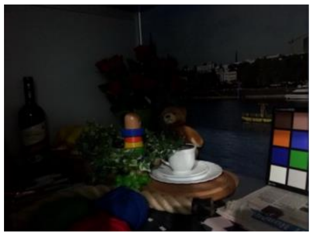
Table 1. The average quality

Method	ENTROPY	PIQE
SUG	7.025	34.598
MBSF[14]	6.814	35.874
CEA[11]	6.496	45.628
FLSMF[1]	6.488	40.475
AHE[7]	6.934	37.169
PNAE[6]	6.675	43.118
LR3M[12]	7.021	36.276

Figure 5. Low lightness data images [16]

(a)

(b)



(c)

(d)

Figure 6. Four images were selected as models for calculating quality

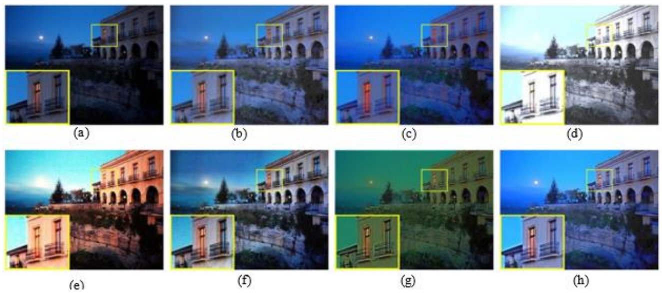


Figure 7. Magnified area of low light images_1: (a) image b in Figure 4 enhanced using the methods, (b) SUG, (c) MBSF, (d) CEA, (e) FLSMF, (f) AHE, (g) PNA and (h) LR3M

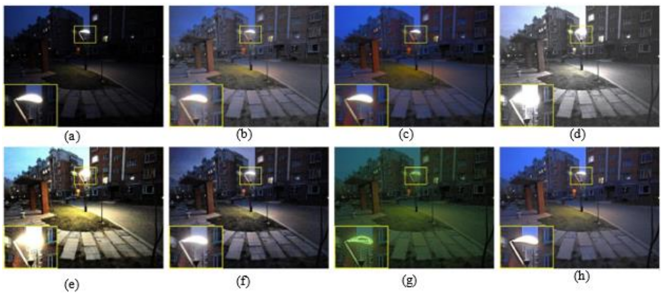


Figure 8. Magnified areas of low light image_4: (a) image b in Figure 4 enhanced using the methods: (b) SUG, (c) MBSF, (d) CEA, (e) FLSMF, (f) AHE, (g) PNA and (h) LR3M

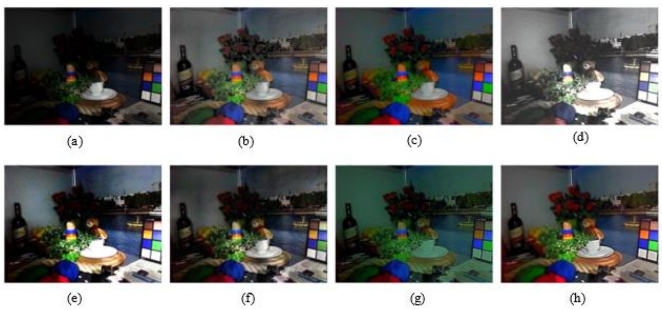


Figure 9. Enhanced low light image _3: (a) image a in Figure 4 enhanced using the methods (b) SUG, (c) MBSF, (d) CEA, (e) FLSMF, (f) AHE, (g) PNA and (h) LR3M

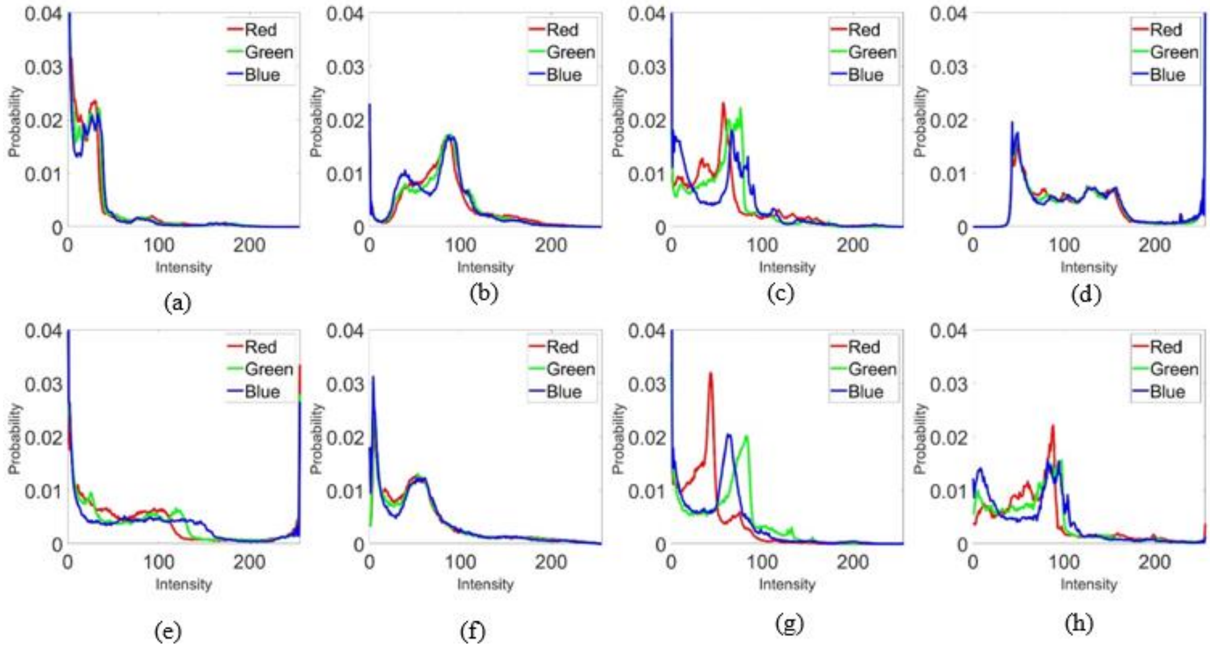


Figure 10. Histograms of low light images in (a) image a in Figure 4 enhanced using various methods: (b) SUG, (c) MBSF, (d) CEA, (e) FLSMF, (f) AHE, (g) PNA and (h) LR3M

Table 2. Quality assessment for images 1, 2, 3 and 4

Image _1			Image _3		
Method	**EN**	**PIQE**	**Method**	**EN**	**PIQE**
SUG	7.403	23.783	SUG	7.085	20.013
MBSF	7.415	23.564	MBSF	7.164	20.590
CEA	6.771	39.497	CEA	6.763	27.249
FLSMF	7.141	27.710	FLSMF	7.210	20.698
AHE	7.467	27.995	AHE	7.392	21.702
PNAE	7.016	40.855	PNAE	6.444	21.313
LR3M	7.319	41.266	LR3M	7.436	48.551
Image _3			**Image _4**		
Method	**EN**	**PIQE**	**Method**	**EN**	**PIQE**
SUG	6.928	23.108	SUG	6.869	33.853
MBSF	6.862	27.317	MBSF	6.633	22.357
CEA	6.902	33.498	CEA	7.067	38.630
FLSMF	6.389	28.498	FLSMF	6.562	41.543
AHE	6.821	25.690	AHE	6.904	37.131
PNAE	6.667	24.669	PNAE	6.652	57.515
LR3M	7.270	68.432	LR3M	6.988	60.185

4. CONCLUSION

In this study, low light images with low contrast are improved using modified (CLAHE) with non-leaner sigmoid mapping based on YIQ colour space. Thus, the lighting component (Y) has been enhanced using CLAHE and sigmoid mapping, and the colour compound (IQ) has been treated via colour restoration. Color conversions are used to reduce any color error after enhancement, as the lighting component can be processed using CLAHE from the lighting component only.

This method is Compared with other algorithms (MBSF, CEA, FLSMF, AHE, PNAE and LR3M) that use quality metrics, the average results of the proposed method are EN (7.403) and PIQE (23.783). Thus, the proposed method effectively improves low light images. This result indicates the algorithm's success to retrieve colour information better than the other methods. In the future, the proposed algorithm can also be used to enhance underwater images and the proposed method can also be developed to improve medical images taken with an optical microscope, such as blood smears. This algorithm can also be used to improve night images, which have many applications such as tracking, object detection, and others applications

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