Contrast Enhancement Algorithm for Colour Images

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***Abstract*—Conventional contrast enhancement techniques often fail to produce satisfactory results for low-contrast images, and cannot be automatically applied to different images because processing parameters must be specified manually to produce satisfactory results for a given image. This paper proposes a contrast enhancement technique to enhance colour images captured under poor illumination and varying environmental conditions. Images are converted from RGB to HSV colour space where enhancement is achieved and reconverted to the RGB. Class Limited Adaptive Histogram Equalization (CLAHE) is used to enhance the luminance component (V). Discrete Wavelet Transform is applied to the Saturation (S) components, and the decomposed approximation coefficients are modified by a mapping function derived from scaling triangle transform. The enhanced S component is obtained through Inverse Wavelet transforms. The image is then converted back to the RGB colour space. Subjective (visual quality inspection) and objective parameters (Peak-signal-to-noise ratio (PSNR), Absolute Mean Brightness Error (AMBE) and Mean squared error (MSE)) were used for performance evaluation. The algorithm implemented in MATLAB was tested images and compared with outputs of HE and CLAHE enhancement techniques. The result shows that the new algorithm gave the best performance of the three methods.**

Keywords—Contrast Enhancement; Class Limited Adaptive Histogram Equalization (CLAHE)

I. INTRODUCTION

Contrast is the difference in luminance or intensity level between objects or regions in an image. If the contrast is too low, all pixels are a mid-shade of gray making the objects to fade into each other. Hence, low contrast causes loss of information in some areas in the image, while good contrast makes objects or scenes depicted in an image distinguishable and visually interpretable for human and machine analysis.

Many algorithms for achieving contrast enhancement have been developed; among them is histogram equalization technique that is attractive due to its simplicity. Histogram equalization generates a grey map that changes the histogram of an image and redistribute all pixel values to be as close as possible to a user-specified desired histogram [1, 2]. An adaptation of histogram equalization is the contrast limited adaptive histogram equalization (CLAHE). CLAHE divides input image into a number of equal size blocks and then performs contrast limited histogram equalization on each block. The contrast limiting is done by clipping the histogram before histogram equalization [2]. Other colour enhancement methods have been proposed based on histogram equalization [3,4], these also include multiscale approaches [5-10] and other hue preservation contrast enhancement schemes [11-14].

Earlier works have also shown that the performance of HSV colour space is good in colour improvement [13]. Hue preservation methods keep the Hue constant to avoid the problem of colour shifting, while either only the Luminance (V) component or both Luminance (V) and Saturation (S) components are modified to make the image soft and vivid.

Compared with other models such as CIE LUV colour space and CIE Lab colour space, it is easier to control the Hue component and still avoid colour shifting in the HSV colour space. Therefore, this work proposes a Hue preserving algorithm, which uses a derived mapping function to modify the Saturation components, and CLAHE for Luminance components.

II. METHODOLOGY

A. Colour Space Conversion

The complete algorithm for the image enhancement method is presented in the flow process below and the flowchart in Figure 1.

Processing Flow/Algorithm

1) *Load a colour image*
2) *Convert from RGB to HSV colour space*
3) *Apply Discrete Wavelet Transform (DWT) to saturation (S) component*
4) *Use a derived mapping function to modify approximate coefficients from (4).*
5) *Reconstruct S using Inverse Discrete Wavelet transform.*
6) *Enhance luminance (V) component using CLAHE.*
7) *Combine H, new S component, and V components to get the enhanced HSV image*
8) *Convert from HSV to RGB colour space.*

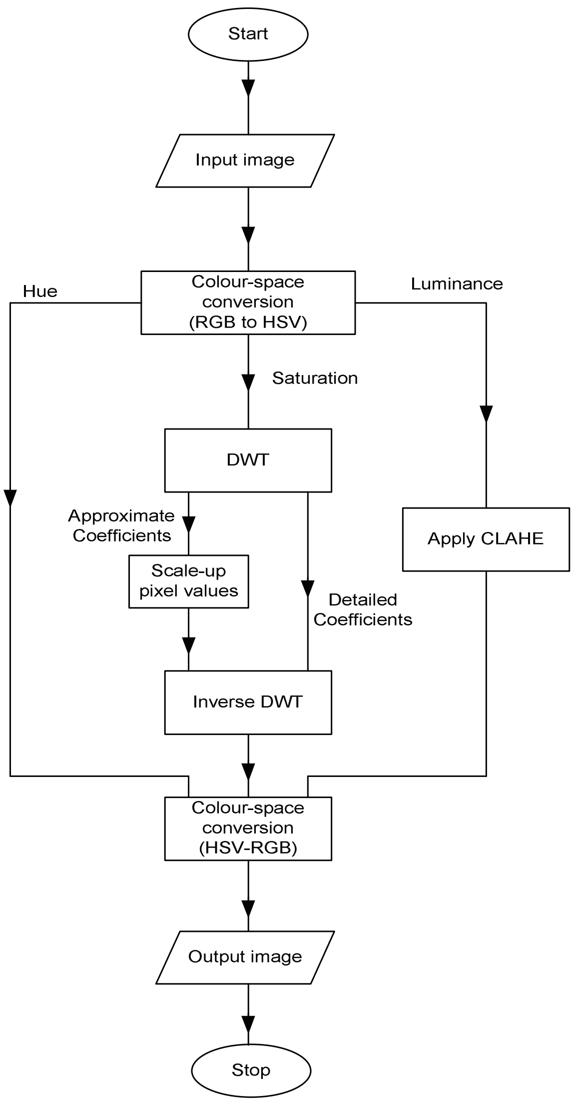

Fig. 1. Block Diagram of Image Enhancement algorithm

Conversion from RGB to HSV colour space is achieved through equations (1) to (5).

$$R' = \frac{R}{255}; \quad G' = \frac{G}{255}; \quad B' = \frac{B}{255} \tag{1}$$

If,

$$C_{max} = \max(R', G', B'); \quad C_{min} = \min(R', G', B'); \quad \text{and } \Delta = C_{max} - C_{min} \tag{2}$$

Then,

$$H = \begin{cases} 60^0 \times \left(\frac{G'-B'}{\Delta} mod6\right), & C_{max} = R' \\ 60^0 \times \left(\frac{B'-R'}{\Delta} + 2\right), & C_{max} = G' \\ 60^0 \times \left(\frac{R'-G'}{\Delta} + 4\right), & C_{max} = B' \end{cases} \tag{3}$$

$$S = \begin{cases} 0 & , \Delta = 0 \\ \frac{\Delta}{C_{max}} & , \Delta <> 0 \end{cases} \tag{4}$$

And $V = C_{max}$ (5)

Inverse conversion to RGB colour space after enhancement is achieved through equations (6) to (12).

$$h_i = \left(\frac{H}{60}\right) mod6, \tag{6}$$

$$f = \frac{H}{60} - h_i, \tag{7}$$

$$p = v \times (1 - s), \tag{8}$$

$$q = v \times (1 - f \times s), \tag{9}$$

And $t = v \times (1 - (1 - f) \times s)$ (10)

For each color vector (r, g, b),

$$(r, g, b) = \begin{cases} (v, t, p), & if h_i = 0 \\ (q, v, p) & if h_i = 1 \\ (p, v, t) & if h_i = 2 \\ (p, q, v), & if h_i = 3 \\ (t, p, q), & if h_i = 4 \\ (v, p, q), & if h_i = 5 \end{cases} \tag{11}$$

the values of R, G, B are

$$R = r \times 256, \quad G = g \times 256, \quad and\ B = b \times 256 \tag{12}$$

B. Contrast Enhancement of Saturation Component.

Discrete Wavelet Transform was applied to the Saturation Component of the image. An enhancement algorithm (derived mapping function) was applied to the approximate component of the wavelet decomposition. Wavelet transform of Image I(x, y) produces S(x, y), which is further decomposed into approximate *A* and detailed components *D* as shown in equation (13)

$$S(x, y) = \sum_{j=0}^{n-1} A_j \emptyset_{jn}(x, y) + \sum_{j=0}^{n-1} \sum_{k=0}^{n} D_{jk} \varphi_{jk}(x, y) \tag{13}$$

Where $\emptyset$ the scale is function and φ is the wavelet function. $A_j{}'s$ are approximate coefficients and $D_{jk}{}'s$ are detail coefficients.

Mapping function for modification of the Saturation component is derived from two equilateral triangles, where one is a scaled version of the other as shown in Figure 2. The minimum value of the decomposed signal is mapped to the base of the 'smaller' triangle, while the maximum value is mapped to the tip of the same triangle. Each value is up-scaled to a new one, represented by an equivalent point on the 'bigger' triangle using the algorithm shown in (14). New minimum and maximum values for the pixels were fixed through a search method and the optimum value that produced the best result selected.

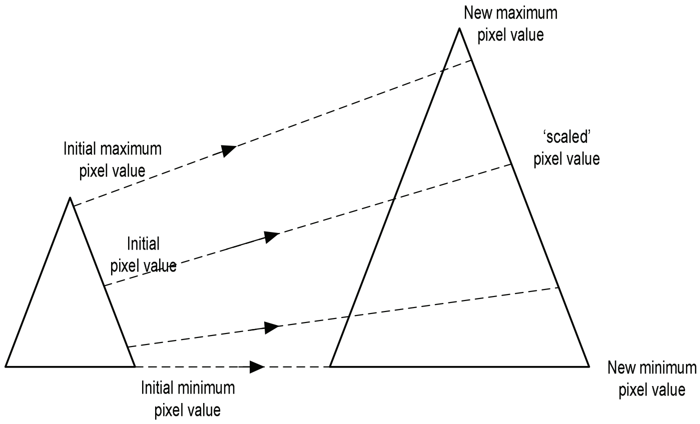

Fig. 2. Scale-up triangle model

$$newmin = (oldmin \times 2.5289);$$
$$newmax = (oldmax \times 0.9)$$
$$For i = 1\ to H; and j = 1\ to W$$
$$newA(i,j) = newmax - \frac{(newmax - oldA(i,j)) \times (newmax - newmin)}{oldmax - oldmin}$$
$$EndFor \tag{14}$$

Where i and j represents the row and column respectively, which stands for the location of a particular approximate component of a pixel.

The enhanced Saturation (S) value is obtained through inverse wavelet transform of the new approximate and original decomposition coefficients.

$$S'(x,y) = \sum_{j=0}^{n-1} A'_j \emptyset_{jn}(x,y) + \sum_{j=0}^{n-1}\sum_{k=0}^{n} D_{jk}\varphi_{jk}(x,y) \tag{15}$$

C. Contrast Enhancement of Luminance Component.

CLAHE was adopted for the enhancement of the V component in the HSV colour space. The V component image is divided into 8×8 tiles. The clip-limit used is 0.01. Uniform distribution is used as the histogram shape for the image tiles.

The expression of modified gray levels for standard CLAHE method with Uniform Distribution can be given as

$$g = [g_{max} - g_{min}] * P(f) + g_{min} \tag{16}$$

Where $g_{max} = maximum\ pixel\ value$

$$g_{min} = mininum\ pixel\ value$$
$$g = comuted\ pixel\ value$$
$$P(f) = cummulative\ probability\ distribution$$

D. Performance Evaluation

1) Absolute mean brightness error (AMBE) is the difference between average intensity level of the original and enhanced image and is given as

$$AMBE = |E(y) - E(x)| \tag{17}$$

Where $|E(x)|$= average intensity of input image $|E(y)|$ =average intensity of enhanced image. Low AMBE indicates a better brightness preservation of the method.

2) Mean-squared-error (MSE) is given as

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}[(r(i,j) - r''(i,j))^2 + (g(i,j) - g''(i,j))^2 + (b(i,j) - b''(i,j))^2] \tag{18}$$

Where $r(i,j), g(i,j), b(i,j), r''(i,j), g''(i,j), b''(i,j)$ are image pixels of original and enhanced image of size $(M * N)$ that corresponds to red, green, and blue respectively. It is the average of the squares of the difference between the original and enhanced image. The lower the MSE, the better the method.

3) Peak-signal-to-noise-ratio (PSNR) is used to evaluate the quality of the reconstructed image. PSNR is measured in decibels (dB) and is given by:

$$PSNR = 10log_{10}\frac{R^2}{MSE} \tag{19}$$

Where $R = 255$ for an 8-bit /class 8 image and $R = 1$ for a double-precision image. The higher the PSNR value, the better the reconstructed image.

III. Experimental Results

The developed algorithm was implemented in MATLAB 7.4.1 and the performance of the system was evaluated using AMBE, MSE and PSNR. Results for three images: architectural model of a shed with a low contrast, satellite impaired by cloud and an image captured in a dark room are shown in Figures 3 to 5 respectively. In each of the figure, (a) shows the original image, while (b), (c) and (d) shows the results of the new method, HE and CLAHE respectively. The visual observation of the images shows that the new method produced a better enhancement. In addition, objective evaluations of the results were also performed using AMBE, MSE and PSNR and the results are presented in Table I.

The AMBE for HE, CLAHE and the proposed method are 75.011, 29.8414 and 22.2189 respectively for Figure 3; -24.5108, -24.0064 and -31.259 respectively for Figure 4 and 94.2895, 24.5988 and 20.0706 respectively for Figure 5. In all the images, the proposed method had the least AMBE, which gives the best brightness preservation of the images. The MSE for the HE, CLAHE and the proposed method are 0.1120, 0.049122 and 0.041426 respectively for Figure 3; 0.11208, 0.10794 and 0.095627 respectively for Figure 4; while it gives 0.11199, 0.026495 and 0.023145 respectively for Figure 5. In all the images, the proposed method has the least the MSE, which also shows that the proposed method performed better than HE and CLAHE. The PSNR for the HE, CLAHE and the proposed method are 21.8927, 30.1346 and 31.8385 respectively for Figure 3; 21.8857, 22.2622 and 23.4730 respectively for Figure 4; while it gives 21.8931, 36.3079 and 37.660 respectively for Figure 5.The proposed method also gave the highest PSNR values, which shows that it produces the best reconstructed image of the three methods.

IV. Conclusion

In this Paper, an algorithm for colour image enhancement has been presented. Modification was performed in HSV colour space, while enhancement achieved in the frequency domain. The Hue component is preserved (unchanged), luminance modified using CLAHE, while Saturation components were up-scaled using a derived mapping function on the approximate components of its discrete wavelet transform. The method performed best when compared with outputs of HE and CLAHE methods, through preservation of image quality and increased dynamic range of image brightness. The method produced images with the lowest MSE AMBE, and highest PSNR. In our future work, we hope to introduce adaptive noise removal, which is expected to give a better result.

TABLE I. RESULTS FOR AMBE, MSE AND PSNR FOR HE, CLAHE AND THE PROPOSED METHOD ON TEST IMAGES

Image	**Shed**			**Satellite Image**			**Image Captured in the Dark**		
Evaluation Parameter	**HE**	**CLAHE**	**Proposed method**	**HE**	**CLAHE**	**Proposed method**	**HE**	**CLAHE**	**Proposed method**
AMBE	75.011	29.8414	22.2189	-24.5108	-24.0064	-31.259	94.2895	24.5988	20.0706
MSE	0.1120	0.049122	0.041426	0.11208	0.10794	0.095627	0.11199	0.026495	0.023145
PSNR (dB)	21.8927	30.1346	31.8385	21.8857	22.2622	23.4730	21.8931	36.3079	37.660

REFERENCES

[1] NaglaeYehya H., and Norio A., (2006),"Contrast Enhancement Technique of Dark Blurred Image", *International Journal of Computer Science and NetworkSecurity,6*(2A), 223-226.

[2] Pfizer S.M, (1987), "Adaptive Histogram Equalization and its Variations," *Computer Vision,Graphics and Image Processing*, *39*, 355-368.

[3] Buzuloiu, V., Ciuc, M., Rangayyan, and Vertan, C., (2001),"Adaptive neighbourhood histogram equalization of color images", *International Journal of Electron Image, 10*(2), 445-459.

[4] Trahanias, P.E. andVenetsanopoulos, A.N., (1992), "Color Image Enhancement through 3-D Histogram Equalization", *Proc. 11th IAPR Conf. on Pattern Recognition*, The Hague,Netherlands, 545-548.

[5] Toet, A., (1992), "MultiscaleColor Image Enhancement", *Pattern Recognition Letters, 13*(3),167–174.

[6] Lu, J., and Hearly, D.M., (1994), "Contrast enhancement via multi-scale gradient transformation", *Proc. SPIE Conf. onWaveletApplication* , Orlando, FL, USA, 345-365.

[7] Brown, T.J., (2000), "An Adaptive Strategy for Wavelet Based Image Enhancement," *Proc.IMVIP Conf. on Irish Machine Vision and Image Processing*, Belfast, Northern Ireland,67-81.

[8] Xiao, D., and Ohya, J. (2007), "Contrast Enhancement of Color Images Based on Wavelet Transform and Human Visual System," *Proc.IASTED Conf. on Graphics and Visualization in Engineering*, Florida, USA, 58-63.

[9] Prabukumar, M., and Cristopher Clement J., (2013). "Compressed Domain Contrast and Brightness Improvement Algorithm for Color Images through Contrast Measuring and Mapping of DWT Coefficients", *International Journal of Multimedia and Ubiquitous Engineering, 8*(1), 55-69.

[10] Numan U., Samil T., and Suleyman D., (2013). "Undecimated Wavelet Transform Based Contrast Enhancement", *International Journal of Computer, information, Systems and Control Engineering 7*(9), 571-574.

[11] Thomas, B.A., Strickland, R.N. and Rodriguez, J.J., (1997), "Colour Image Enhancement Using Spatially Adaptive Saturation Feedback", *Proc. 4th IEEE Conf. on Image Processing*, SantaBarbara, CA, USA, 30-33.

[12] Gupta, A., and Chanda, B., (1996). "A Hue Preserving Enhancement Scheme for a Class of Color Images", *Pattern Recognition Letters, 17*(2), 109-114.

[13] Naik, S.K.and Murthy, C.A., (2003), "Hue-Preserving Color Image Enhancement without Gamut Problem", *IEEE Trans. on Image Processing, 12*(12), 1591-1598.

[14] David Menotti, Laurent Najman, Jacques, Facon, and Arnaldo de A., (2012). "Fast Hue Preserving Histogram Equalization Method for Color Image Contrast Enhancement", *International Journal of Computer Science & Information Technology 4*(5), 243-259.

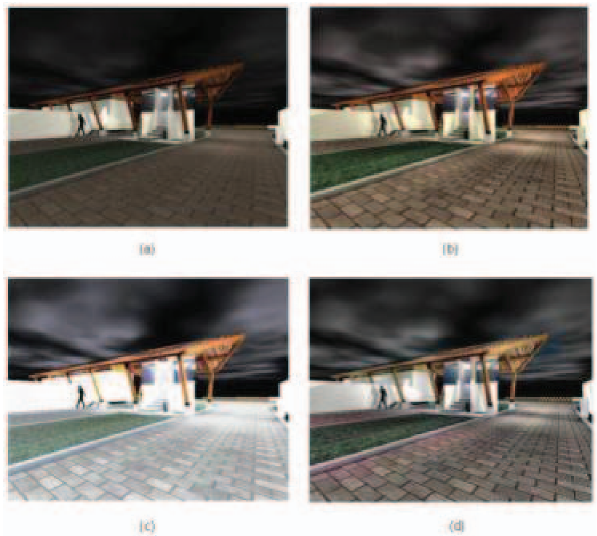

Fig. 3. Shed

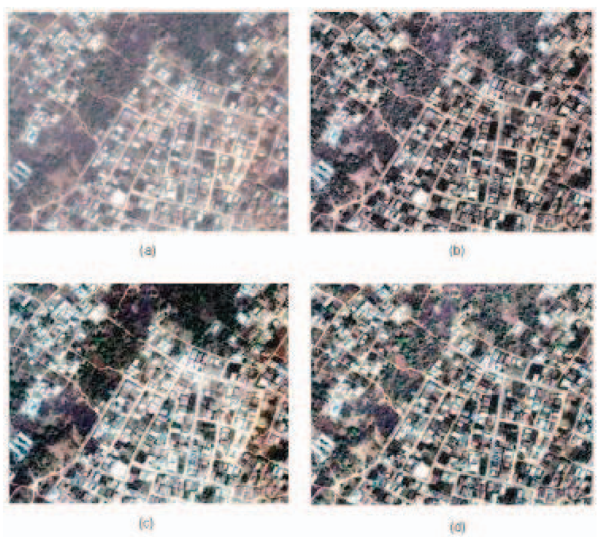

Fig. 4. Satellite Image

a) Original images
b) Output of the new enhancement method
c) Output of the HE method
d) Output of the CLAHE method.

Fig. 5. Image Captured in a dark room