High Lightness Image Enhancement Using Adaptive Histogram Equalization Algorithm

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الخلاصة

الهدف الرئيسي من تحسين الصورة هو معالجتها للحصول على صور افضل من الصورة الاصلية ولتطبيق محدد. في هذا البحث تم تقديم خوارزمية تحسين جديدة لتحسين الصور عالية الاضاءة هي خوارزمية تسوية الهستوغرام المقترحة بالاعتماد على فضاء YIQ عن طريق معالجة مركبة الاضاءة فقط ثم استخدام التحويل العكسي من هذا الفضاء الى الفضاء الاساسي RGB ثم صححت الالوان باستخدام نظرية تعتمد على نظام الرؤية للانسان. تمت مقارنة النتائج مع خوارزمية تسوية الهستوغرام عن طريق حساب معدل مربع الخطأ العياري بين الصورة الاصلية ذات الاضاءة الجيدة والصورة المعالجة كذلك المخططات التكرارية لكلا الطريقتين اخذت بنظر الاعتبار. الخوارزمية المقترحة اظهرة كفاءة افضل في تحسين الصور عالية الاضاء عند مقارنتها مع خوارزمية تسوية الهستو غرام.

ABSTRACT

The Principle objective of Images enhancement is to process an image so that result is more suitable than original image for specific application. This search describe a new image enhancement algorithm which is apply to enhance low lightness images called adaptive histogram equalization AHD algorithm dependent on YIQ color space via processed only lightness component then used inverse transformation from YIQ color space to basic color space and color correction dependent on retinex theory. The results was compared with Histogram Equalization HE algorithm by calculate normalize mean square error NMSR between processed images and original images with fair lightness, histogram of both method enhancement was a account. Adaptive algorithm has best efficiency in enhanced low lightness compared with HE algorithm.

Keywords: contrast, high lightness, Histogram Equalization, adaptive Histogram Equalization, color transformation.

INTRODUCTION

Producing digital images with good brightness/contrast and detail is a strong requirement in several areas including vision, remote sensing, biomedical image analysis, and fault detection. Producing visually natural images or transforming the image such as to enhance the visual information within is a primary requirement for almost all vision and image processing tasks. Methods that implement such transformations are called image enhancement techniques (1,2). Histogram equalization and its variations have traditionally been used to correct for uniform lighting and exposure problems. This technique is based on the idea of remapping the histogram of the scene to a histogram that has a near-uniform probability density function. This results in reassigning dark regions to brighter values and bright regions to darker values. Histogram equalization works well for scenes that have unimodal or weakly bi-modal histograms (i.e. very dark, or very bright), but not so well for those images with strongly bi-modal histograms (i.e. scenes that contain very dark and very bright regions) (3) there are number of studies as following:

1. D. J. Jobson, Z. Rahman, and G. A. Woodell 1996: introduced new algorithm to improve the brightness, contrast and sharpness of an image. It performs a non-linear spatial/spectral transform that provides simultaneous dynamic range compression (4).
2. B. V. Funt, K. Barnard, M. Brockington, and V.Cardei 1997: introduced investigations into Multi-Scale Retinex algorithm approach to image enhancement to explain the effect of the processing from a theoretical standpoint (5).
3. Mark Grundland and Neil A 2004. Dodgson presented an automated algorithm for global contrast enhancement of images with multimodal histograms. To locate modes and valleys, histogram analysis is performed by kernel density estimation, a robust nonparametric statistical method (6).
4. Osman Nuri & Capt. Ender 2007 proposed a new algorithm to enhance night scenes and under nonuniform lighting conditions, either the low intensity areas or the high intensity areas cannot be clearly seen dependent on non linear transform (7).
5. Nabeel M. Al Dalawy 2008: This research aimed to study the Quality of TV images and determined the type of the noise and the relationship between the mean and the standard deviation for regions illumination components of small rotating angles of the antenna. (8).

In this work, we introduce a new enhancement algorithm used to enhancement high lightness image called adaptive Histogram equalization (AHE) algorithm this algorithm dependent on traditional HE , processing lightness component in YIQ color space and logarithm function to correct color image. The outline of this paper is as follows: Section 2 shown histogram equalization. Section 3 describes the adaptive histogram equalization. Results and discussion are shown in Section 4, finally conclusion shown in Section 5

Histogram Equalization (HE)

A global technique that works well for a wide variety of images is histogram equalization (HE) If lightness levels are continuous quantities normalized to the range (0, 1), $p_r(r)$ denote the probability density function (PDF) of the lightness levels in a given image, where the subscript is use for differentiating between the PDFs of the input and output images. Suppose that is performed the following transformation on the input levels to obtain output (processed) intensity levels (9),

$$s = T(r) = \int_0^r p_r(w)dw \qquad \text{.....................................(1)}$$

Where w is a dummy variable of integration, that the probability density function of the output levels is uniform, that is[9]:

$$P_s(s) = \begin{cases} 1 & for \quad 0 \le s \le 1 \\ 0 & otherwise \end{cases} \quad \text{.....................................} (2)$$

When dealing with discrete quantities worked with histograms and called the preceding technique histogram equalization, where (4):

$$s_k = T(r_k) = \sum_{j=0}^{k} p_r(r_j) = \sum_{j=o}^{k} \frac{n_j}{n} \qquad k = 0.....L \qquad \text{.........} (3)$$

Where: r_k is normalized intensity level of the input image corresponding to the (un-normalized) intensity level k: $\mathrm{r_k} = \frac{k}{L}$ (r_k=0..1) and (k =0.....L-1) and L =256 for lightness band with 8 bit/pixel), s_k corresponding normalized intensity level of the output image .The cumulative probability density function (CPDF) calculated by[9]:

$$p_c(r_k) = \sum_{j=0}^{k} p_r(r_j) = \sum_{j=0}^{k} \frac{n_j}{n} \qquad \text{.....................................} (4)$$

r_j is normalized intensity level of the input image corresponding to the (un – normalized) intensity level j , and r_j given by :

$$r_j = \frac{j}{L} \quad , j = 0...L-1. \qquad \text{.....................................} (5)$$

Where n_j being the number of pixel with intensity j and n is the total number of pixel of the image this algorithm done by using following steps:

1. Input color image $C(n,m,i)$, $i=1,2,3$ (red ,green& blue) components.
2. Normalize each component $r_j(i)= C(n,m,i)/ 255$ and calculated iteration of each gradual level $n_j(i)$, where $j=0,1,..255$.
3. Compute histogram from $P(r_j(i))=n_j(i) /N$, where N being the size of image.
4. Calculate cumulative histogram by :

$$s_k(i) = \sum_{j=0}^{k} \frac{n_j(i)}{N} \quad \text{where } k=0,1,..255 .$$

5. *Replaced each normalized component $r_{j\,(i)}$ by value of $s_k(i)$ and we get out put image .*

3. Adaptive Histogram Equalization (AHE).

First step in the AHE is transform color image from basic RGB color space to YIQ color space and processing Y component only by using traditional HE algorithm, the forward transform given from following equations [10]:

$$\left.\begin{aligned} y &= 0.299r + 0.587g + 0.114b \\ i &= 0.596r - 0.27g + 0.322b \\ q &= 0.211r - 0.253g + 0.312b \end{aligned}\right\} \quad \text{.....................................} (6)$$

Where y is lightness component, i,q are chromatic components and r,g,b being red ,green and blue components of RGB color space respectively. And then inverse transformation used from YIQ to RGB given by (11):

$$\left.\begin{aligned} r &= y + 0.956i + 0.621q \\ g &= y - 0.272i - 0.647q \\ b &= y - 1.106i + 1.703q \end{aligned}\right\} \qquad \text{.....................................} \ (7)$$

The lightness component has ratio of 80% from the data of image [10]. Second step is color correction or color restoration scheme that provides good color rendition for images that contain gray-world violations[12]. This method inspiration from retinex theory dependent on human visual perception from logarithm function given by(13):

$$In_i(x,y) = Ihe_i(x,y).I_i'(x,y,a) \qquad \text{.....................................} \ (8)$$

Where

$$I_i'(x,y,a) = \log[1 + a\frac{I_i(x,y)}{\sum_{i=1}^{3} I_i(x,y)}] \qquad \text{.....................................} \ (9)$$

Where $Ihe_i(x,y)$ is histogram equalization of the image results from inverse transformation from YIQ color space , $I_i(x,y)$ is original color image

(i=1,2,3 being red, green and blue bands) and a is default constant equal 120 in this work , we have taken the liberty to use *log(1+x)* in place of log(x) to ensure a positive result.

The data results from equation (8) has negative value and its histogram has large tails, thus finely step is gain-offset by 0.35 and 056 respectively where:

$$Iahe_i(x,y) = 0.35(In_i(x,y) + 0.56) \qquad \text{.....................................} \ (10)$$

AHE algorithm can be done from following steps:

1. Input color image *C(n,m)*.
2. Transform color image *C(n,m)* from *RGB* space to *YIQ* space and estimated lightness component *Y(n,m)*.
3. Normalize lightness component $r_j = Y(n,m)/255$ and calculated iteration of each gray level n_j , where $j=0,1,..255$.
4. Compute histogram from $P(r_j)=n_j/N$, where N being the size of image.
5. Calculate cumulative histogram by :

$$s_k = \sum_{j=0}^{k} \frac{n_j}{N} \quad \text{, where } k=0,1,..255 \ .$$

6. Replaced each normalized component r_j by value of s_k and we get processing lightness component $Y_p(n,m)$.

7. Transform image from Y_pIQ to RGB color space, we get $Ihe_i(x,y)$.

8. Calculate color correction from $In_i(x,y) = Ihe_i(x,y).I_i'(x,y,a)$,where

$$I_i'(x,y,a) = \log[1 + a\frac{I_i(x,y)}{\sum_{i=1}^{3} I_i(x,y)}]$$, a=120 .

9. Computed gain-offset value of $I_i'(x,y,a)$ from

$$Iahe_i(x,y) = 0.35(In_i(x,y) + 0.56)$$

Where $Iahe_i$(x,y) being output image.

RESULTS AND DISCUSSION

In this work we captured four images from (Sony digital camera) with size (320×240) bmp type, two image with high lightness and another with moderate lightness (fair or original images) as shown in figure(1) . Original images are used to compare with processing images by calculated normalized mean square error (NMSE) that given by[10]:

$$NMSE = \frac{1}{N \times M}\sum_{x=1}^{N}\sum_{y=1}^{M}(\frac{Io(x,y) - Ip(x,y)}{255})^2 \qquad \text{.......... (11)}$$

Where Io being the lightness of fair image captured with preparation lightness its size (N×M) and Ip is the lightness of processing image resulted from HE, and AHE algorithm.

From figure (2-a , 2-c) we noted in AHE enhanced images were more obvious however, increased contrast and lightness compared with image enhancement by using HE as in figure (2-b, 2-d) .While in figure (2-e,f,g & h) shown histogram distribution of high lightness images and fair images, we noted in high lightness image the histogram nears from white region due to high lightness, however in enhancement images the histogram nears from histogram of fair images as in figure (2-e,f,g & h) with increasing in variance. The distribution of histogram in processing images reflected in NMSE as shown in table (1) appeared from these values the minimum value in image enhanced by AHE algorithm.

Table- 1: NMSE values for high lightness image and enhanced images resulted from HE , AHE algorithm.

Image	High lightness	HE	ADH
(a)	0.0952	0.0761	0.0742
(b)	0.0821	0.0٦٠٧	0.0438

The AHE algorithm is efficiently method to enhance high lightness images compared HE Algorithm due to color correction that restorated in AHE. This algorithm is restored many features that lost in high image because high illumination due to increase the lightness and decrease the contrast in high lightness images.

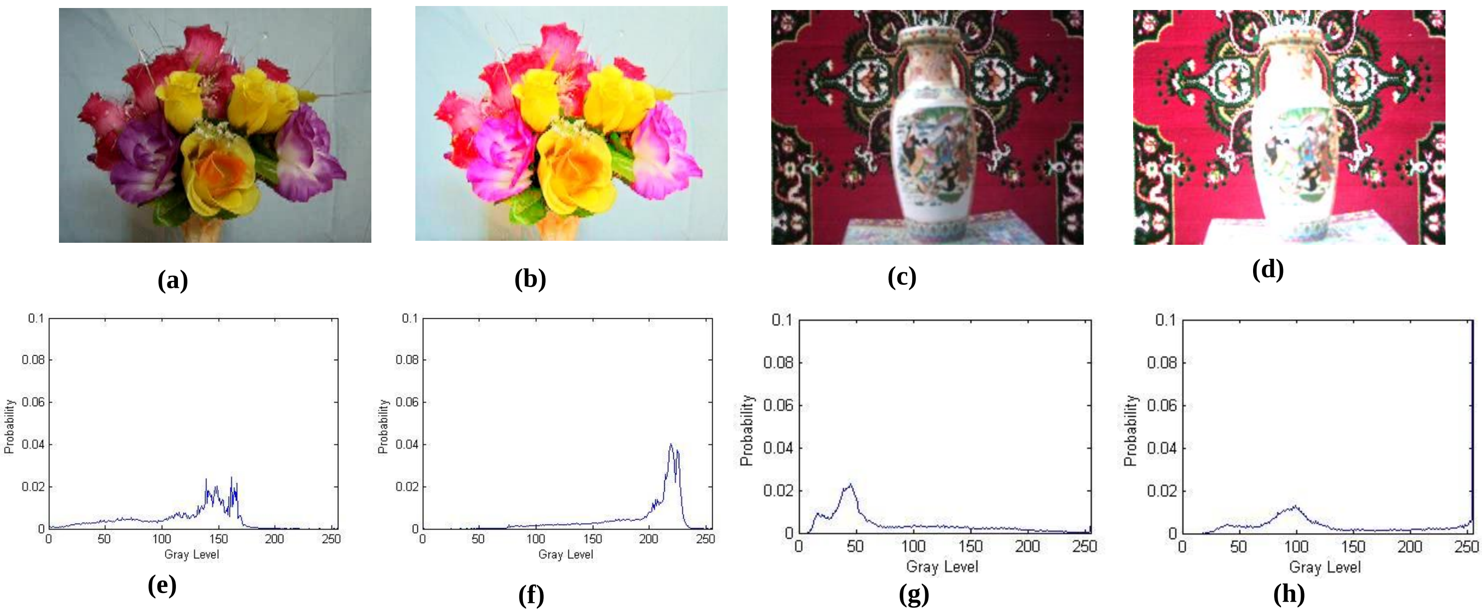

Figure -1: Upper row represent :
(a) Original image 1. (b) High lightness images 1. (c) Original images 2. (d) High lightness l images 2.
Lower row represent: histogram of (a), (b) ,(c)and(d) images respectively.

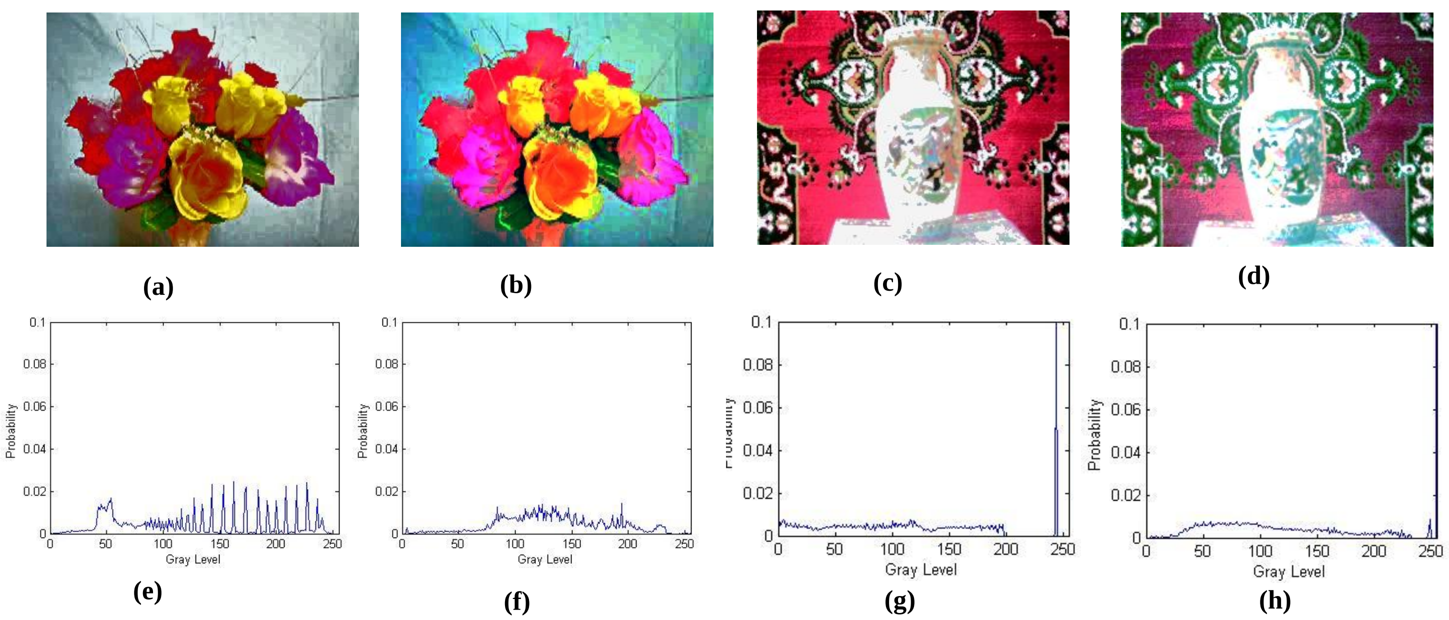

Figure -2:Upper row represent:
(a) Images 1 enhancement by using AHE . (b image 1 enhancement by using HE.
(c) Images 2 enhancement by using AHE. (d) Image 2 enhancement by using HE.
Lower row represent: histogram of (a), (b) ,(c)and(d) images respectively.

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