Color image with Dim regions Enhancement Using Modified Histogram Equalization Algorithm

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Abstract

In this paper the color images with dim regions have been enhanced by using modified histogram equalization (MHE) algorithm. This technique uses the lightness component in YIQ color space is transformed using sigmoid function, then the traditional histogram equalization (HE) method is applied on Y component. A relationship between the mean and the average of standard deviation for images have been done for images with dim regions and select regions in these images, as well the histogram to examine the efficiency of the work. The result of MHE method has been compared with the result of other method like Adaptive Integrated Neighborhood Dependent Approach for Nonlinear Enhancement of Color Images (AINDANE) and traditional histogram equalization algorithm. All algorithms has implemented using program (Matlab). The suggestion algorithm appeared good enhancement for both regions with moderate and low lightness (dim region) compared with others algorithms.

Keywords: histogram equalization, adaptive histogram equalization, sigmoid function, Contrast and lightnes enhancement.

Introduction

A common and often serious discrepancy exists between recorded color images and the direct observation of scenes. Human perception excels at constructing a visual representation with vivid color and detail across the wide range of photometric levels due to lighting variations. In addition, human vision computes color so as to be relatively independent of spectral variations in illumination [1].

When attempting to display an image on a display device, either the low intensity areas (dim region), which are underexposed, or the high intensity areas, which are overexposed, cannot be seen. To handle this problem, various image processing techniques have been developed. Some of them are simple methods such as histogram equalization, gamma adjustment, and logarithmic method. 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 strong bi-modal histograms (i.e. scenes that contain very dark and very bright regions) [2].

A number of researches have been conducted to study the contrast and lightness color image enhancement in different ways, in the following some of these 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 [3]. This method is compared with other enhancement Techniques like Histogram equalization and homomorphic filtering [2].
2. B. V. Funt, K. Barnard, M. Brockington, and V.Cardei 1997: have investigated the Multi-Scale Retinex algorithm approach to image enhancement, they explained the effect of processing from theoretical standpoint [4], and in the same year they modified the multi-scale retinex approach to image enhancement such that the processing is more justified from a theoretical standpoint they suggested a new algorithm with fewer arbitrary parameters and prove it is more flexible [5].
3. A.N.H. Al-Biaty 2005: had evaluated image quality depending on computing the image contrast in edge regions, she introduced

robust quantitative measures to determine image quality, then estimate the efficiency of the various techniques in image processing applications. In this study she suggested a new technique to calculate image contrast (visibility) [6].

4. Li Tao, Ming-Jung Seow and Vijayan K. Asari in 2006: proposed image enhancement technique to improve the visual quality of digital images that exhibit dark shadows due to the limited dynamic ranges of imaging and display devices which are incapable of handling high dynamic range scenes. The proposed technique processes images by applying two separate steps: dynamic range compression and local contrast enhancement. Dynamic range compression is a neighborhood dependent intensity transformation which is able to enhance the luminance in dark shadows while keeping the overall tonality consistent with that of the input image [7].
5. Ali J. Al Dalawy 2008: He studied the TV-Satellite images of "Al-Hurra" channel broadcasted on Arabsat, Hotbird and Nilesat. These images were the same with respect to the type on the three satellites. The analyzing these images was done statistically by finding the statistics distribution and studying the relations between the mean and the standard deviation of the color compound (RGB) and light component (L) for the image as whole and for the extracted homogeneous regions. Also he studied the contrast of image edges depending on sobel operator in neighbor area to the edges and studied the contrast as function for edge finding threshold. He found the Hotbird has the best results [8].

Histogram Equalization

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

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

Where w is a dummy variable of integration. The probability density function of the output levels is uniform, such that [4]:

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

When dealing with discrete quantities, we will work with histograms, and call the preceding technique histogram equalization, such that [9]:

$$s_k = T(r_k) = \sum_{j=0}^{k} p_r(r_j) = \sum_{j=o}^{k} \frac{n_j}{n} \quad , j = 0.....k$$

$$\text{....................................(3)}$$

Where: r_k is the normalized intensity level of the input image corresponding to the (non-normalized) intensity level k: $r_k = \frac{k}{L}$ (r_k $=0..1$) and (k $=0..L$) and L $=255$ for lightness band with 8 bit/pixel), s_k corresponds to normalized intensity level of the output image. The cumulative probability density function (CPDF) calculated by[9]:

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

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

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

Where n_j being the number of pixel with intensity j and n is the total number of pixels of the image. Matlab code (1): HE algorithm.

```
c = imread('w1.bmp');          % read input  image w1
J(:,:,1) = histeq(c(:,:,1));   % HE for   red band
J(:,:,2) = histeq(c(:,:,2));   % HE for  green band
J(:,:,3) = histeq(c(:,:,3));   % HE for blue band
imshow(J)                      % display output image J
```

AINDNE Algorithm

Adaptive Integrated Neighborhood Dependent Approach for Nonlinear Enhancement of Color Images (AINDANE) [7] is an algorithm to improve the visual quality of digital images captured under extremely low or uniform lightening conditions. it is composed of three main parts:

adaptive Luminance enhancement, contrast enhancement and color restoration, this algorithm can be discus as following [7]:

a. Adaptive luminance enhancement: is consist of two steps, the first step is luminance estimation to obtain by conversion of the luminance information by using National Television Standards Committee (NTSC) color space. Intensity values of RGB image can be obtained using the following [10]:

$$I(x,y) = 0.298r + 0.587g + 0.114b \quad \text{........... (6)}$$

Where r,g,b are the red, green, blue components for the color image in RGB space. And the normalized intensity is:

$$I_n(x,y) = I(x,y)/255 \quad \text{..............................(7)}$$

The image information according to human vision behavior can be simplified and formulated as [7]:

$$I(x,y) = L(x,y)R(x,y) \quad \text{............................(8)}$$

Where $R(x,y)$ is the reflectance and $L(x,y)$ is the illumination at each position (x,y), the luminance L is assumed to be contained in the low frequency component of the image while the reflectance R, mainly represents the high frequency components of the image. For estimation of illumination, the result of Gaussian low-pass filter applied on the intensity image is used. In spatial domain, this process is a 2D discrete convolution with a Gaussian kernel which can be expressed as:

$$I_c(x,y) = L(x,y) = I(x,y) \otimes F(x,y,c) \text{.........(9)}$$

The I_c is image convolution, symbol $\otimes$ denotes convolution. $F(x,y,c)$ Gaussian surrounds function that is calculated by:

$$F(x,y,c) = k\exp\left(\frac{-(x^2 - y^2)}{c^2}\right) \quad \text{..................(10)}$$

k is determined using the condition:

$$\iint F(x,y,c)\,dx\,dy = 1 \quad \text{............................(11)}$$

The second step is called adaptive dynamic range compression of illuminance it can be applied using the transfer function I'_n by [19]:

$$L_n = \frac{I_n^{0.24} + (1 - I_n)0.5 + I_n^2}{2} \quad \text{....................(12)}$$

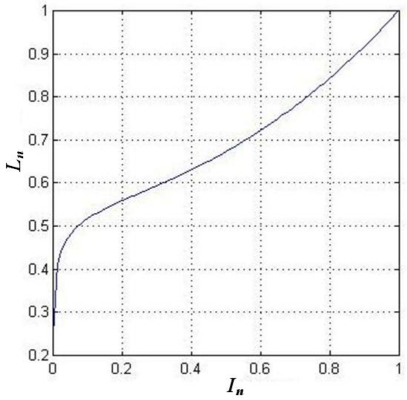


Fig.(1) The relationship between the input I_n versus output lightness L_n in AINDANE.

This transformation can largely increase the luminance for the dark pixels, Fig.(1) illustrate the relationship graphically.

b. contrast enhancement: is done by Center-surround contrast enhancement by using[7] :

$$R(x,y) = 255L_n(x,y)^{E(x,y)} \quad \text{................. (13)}$$

$$E(x,y) = \left[\frac{I_c(x,y)}{I(x,y)}\right]^p \quad \text{..................................(14)}$$

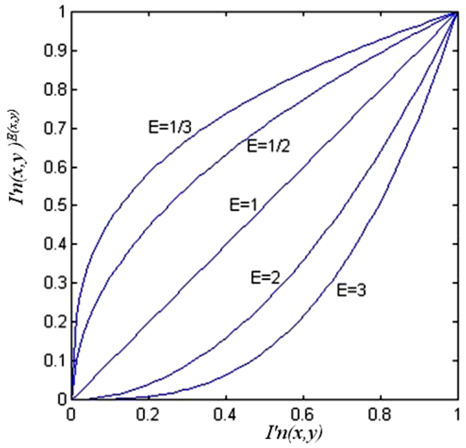


Fig.(2) Relationship between normalized $I'_n(x,y)$ and $I'_n(x,y)^{E(x,y)}$ in different values of E(x,y).

Where p constant can be manually adjusted by users to tune the contrast enhancement process generally its value is $(0.5 \le p \le 2)$ it dependent on the global standard deviation of the input intensity image. According to this method, if the center pixel's intensity is higher than the average intensity of surrounding pixels, the corresponding pixel on the intensity-enhanced image will be pulled up, otherwise it will be pulled down. In fact, this process is an intensity transformation process. Considering the enhanced-intensity pixels are in the range [0 1] and the power of these pixels as in Fig.(2).

c. Color restoration: a linear color restoration process is applied, it is based on the chromatic information of the original image. It is applied to convert the enhanced intensity image to RGB color image. The (r',g',b') of the restored color image are obtained by [2]:

$$r' = h\frac{R}{I}r \quad , \quad g' = h\frac{R}{I}g \quad , \quad b' = h\frac{R}{I}b \qquad \text{..................................(15)}$$

$$R(x,y) = \sum_i w_i R_i(x,y) \qquad \text{..............................(16)}$$

Where i=1,2,3,…represents different scales (c_i) and w_i is the weight factor for each constant enhancement and (R_1,R_2,R_3) were calculated from equation (13) . The scales used in this search are [11]: $c_1=5$, $c_2= 20$ and $c_3=240$ and $w_1=w_2=w_3=1/3$.In this papers we called this algorithm (Li algorithm).

Matlab code (2): Li algorithm implementation

```
x =double(imread('w1.bmp'));
 nw=size(x,1);,nh=size(x,2); % read width & height of
                                          %        image
h=.8  ;,p=1
YIQ = rgb2ntsc(x); % transform image to YIQ color space
I = YIQ(:,:,1);       % read lightness component
In=I/255;
Int=(In.^0.24+(1-In)*0.5+In.^2)/2;
    n=nw/2;
  scale=5;
im1=(gus(I,scale,n));      % calculate Gaussian convolution
% in frequency   domain  for image I in   different scales
  scale=20;
im2=(gus(I,scale,n));
  scale=204;
im3=(gus(I,scale,n));
f1=im1./(I+eps);
f2=im2./(I+eps);
f3=im3./(I+eps);
for i=1:nw;
    for j=1:nh;
Ir1(i,j)=Int(i,j).^f1(i,j) ^p;
Ir2(i,j)=Int(i,j).^f2(i,j) ^p;
Ir3(i,j)=Int(i,j).^f3(i,j) ^p;
    end
end
Ir=(Ir1+Ir2+Ir3)/3;
ir=(x(:,:,1).*(Ir./(I+eps)));
ig=(x(:,:,2).*(Ir./(I+eps)));
ib=(x(:,:,3).*(Ir./(I+eps)));
imag(:,:,1)=ir;
imag(:,:,2)=ig;
imag(:,:,3)=ib;
imag= h*imag;
imshow((imag));
```

Matlab code (3): Gaussian convolution (gus) computation in frequency domain

```
function  img2=gus(I,scale,n)
fim=fft2(I);
for i=1:size(scale,2);
   [x y]=meshgrid((-(size(I,2)-1)/2):(size(I,2)/2),(-
(size(I,1)-
1)/2):(size(I,1)/2));
   gauss=exp(-(x.^2+y.^2)/scale(i)^2);
   gaus=gauss/sum(gauss(:));
    fgauss=abs(fft2(gaus,size(I,1),size(I,2)));
    for j=1:size(I,3);
       fg(:,:,j)=fgauss;
    end
   imag=abs(ifft2(fg.*fim));
   end
   img2=(imag/(size(scale,2)*(4-size(I,3))));
```

Modified Histogram Equalization Algorithm

First step in this algorithm is transform color image from basic RGB color space to YIQ color space, the forward transform is given by [١٠]:

$$\left.\begin{aligned} y &= I \\ i &= 0.596r - 0.27g + 0.322b \\ q &= 0.211r - 0.253g + 0.312b \end{aligned}\right\} \qquad \text{..............(17)}$$

Where y is lightness component, i,q are chromatic components.In second step is transformed normalized lightness value by using sigmoid function that is given by [12]:

$$S_n = 1/(1+\sqrt{\frac{1-I_n}{I_n}}) \qquad \text{.......................................(18)}$$

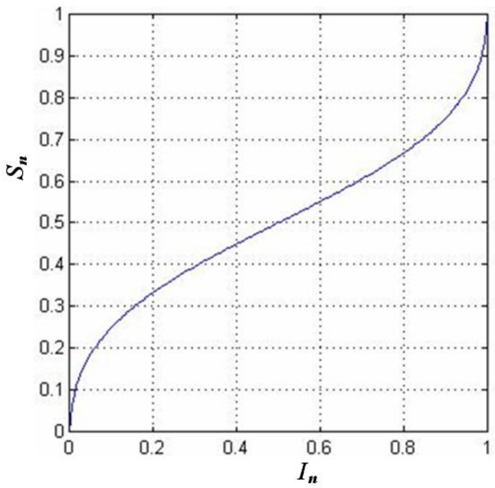


Fig.(3) Relationship between input lightness I_n versus output lightness Sn in MHE.

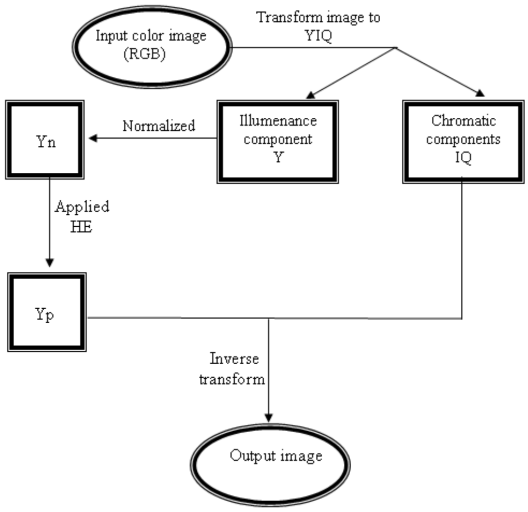


Fig.(4) Stages of MHE algorithm.

Third step is applied HE on modify lightness component, the processing lightness component Y_P has been get form this step.

Finally inverse transformation from YIQ to RGB color space calculated in Y_PIQ that is given by [10]:

$$\left.\begin{aligned} r &= y_p + 0.956i + 0.621q \\ g &= y_p - 0.272i - 0.647q \\ b &= y_p - 1.106i + 1.703q \end{aligned}\right\} \quad \text{........................(19)}$$

The stages of MHE algorithm are shown in Fig.(4).

Matlab code (4): MHE algorithm implementation

```
imo =(imread('w5.bmp'));
YIQ = rgb2ntsc(imo);
I = YIQ(:,:,1);
I2 = YIQ(:,:,2);
I3 = YIQ(:,:,3);
In=I; % normalazed light image
Int=1./(1+((1-In)./(In+eps)).^0.5);
 J(:,:,1) = histeq(Int(:,:,1));
 J(:,:,2) = I2;
 J(:,:,3) = I3;
img= ntsc2rgb(J);
imshow((imag));
```

Measurement of Image Quality

Some researchers in NASA Langley research center [13] concluded heuristics to measure quality of the image, proposed the idea that good visual representations seem to be based upon some combination of high regional visual lightness and contrast. To compute the regional parameters, we divide the image into non overlapping blocks that are 50×50 *pixels*. For each block, the mean (I) and a standard deviation (σ) are computed, and then taking the mean of them $\bar{I}$ and $\bar{\sigma}$ as shown in Fig.(5).

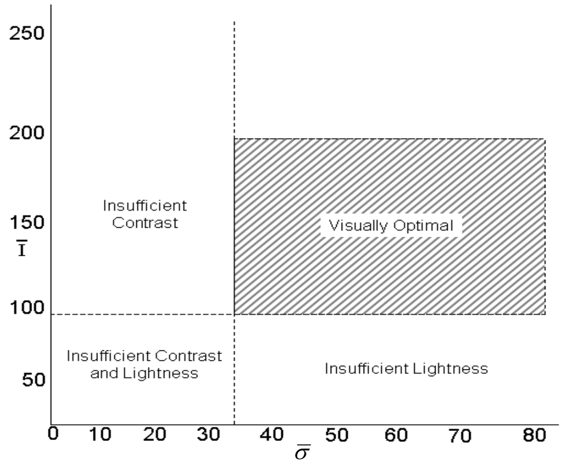


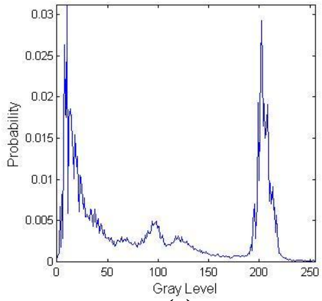
Fig. (5) Image quality description [13].

If the points tend to visual optimal region the image has higher quality of lightness and contrast, whereas if $\bar{\sigma}$ (without $\bar{I}$) is increased it makes image has insufficient lightness, but if $\bar{I}$ (without $\bar{\sigma}$) is increased it makes insufficient contrast in the image.

Discussion and Conclusions

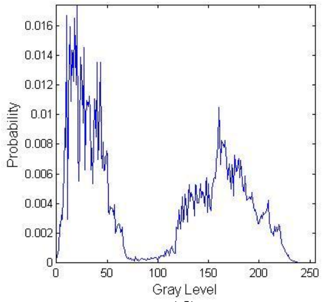
The images used in this study are illustrated in Fig.(6) [14]. These images were enhanced using different algorithms as shown in Figs. (7 & 11), the best enhancement has obtained when using MHE algorithm in both regions (dim and moderate lightness). In images enhancement by Li algorithm, this algorithm has succeeded in increasing the lightness to a great degree but not the same degree in contrast, in image enhanced by HE algorithm in color of some regions was significantly shafted due to the processing on basic components RGB with high corrections. The histograms in Figs. (7 & 11) showed the modified method (MHE algorithm), this algorithm was enabled to increase both lightness and contrast in images. Figs. (8 & 12) shown the positions of select regions in original images and its histograms whereas Figs. (10 and 14) show the histogram of enhanced images, we can note the behavior of distribution is similar in histograms of all images and this reflected in relationship between mean of local standard deviations and mean for images and select regions in it is illustrated in (9 and 13) the points of MHE tend to visual optimal region compared with other points. We can conclusion the MHE is robust method to enhanced color image with deferent lightness levels.

(a) Image I



(c)

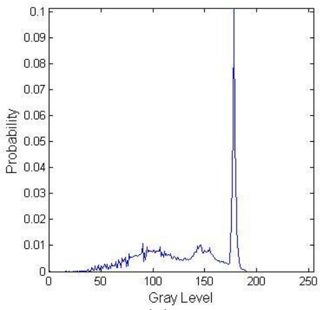
(b) Image II



(d)

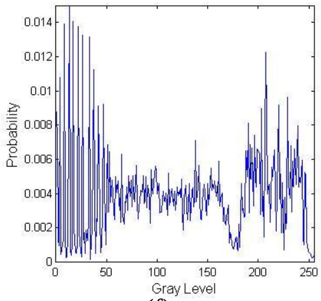
Fig.(6) Images and their histograms.

(a)

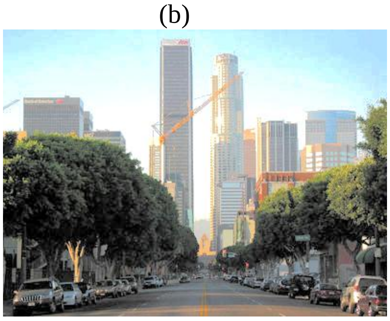


(e)

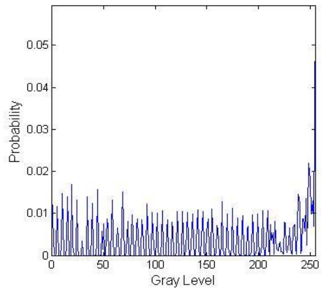
(b)



(f)



(c)



(g)

Fig. (7) The results of the enhanced image (I) and its histogram using Li, HE and MHE respectively.

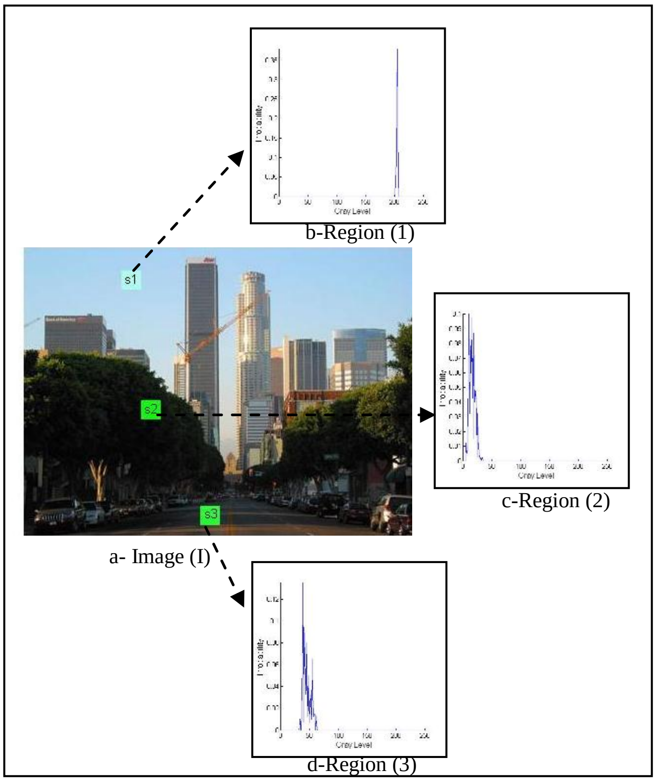


Fig.(8) Positions of select regions and its histograms in images (I) .

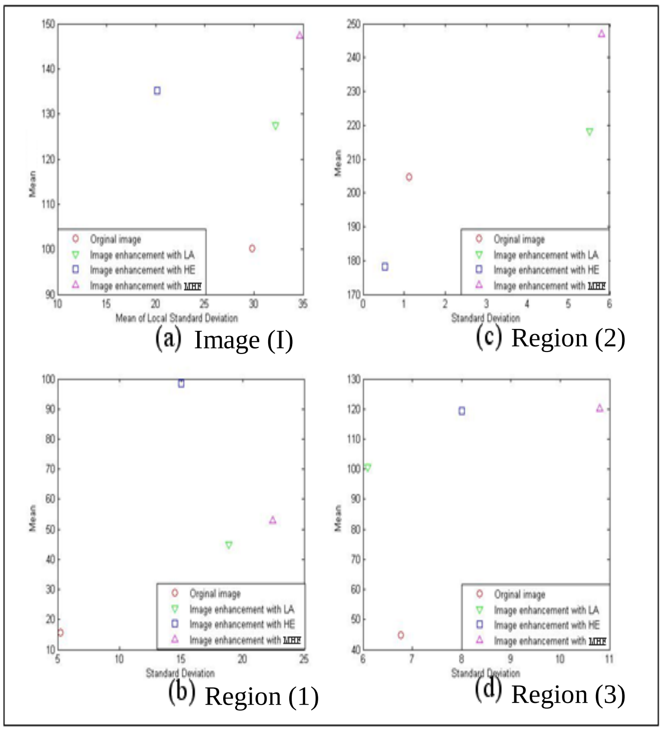


Fig.(9) Relationship between mean of local standard deviations and mean of image (I) and its select regions.

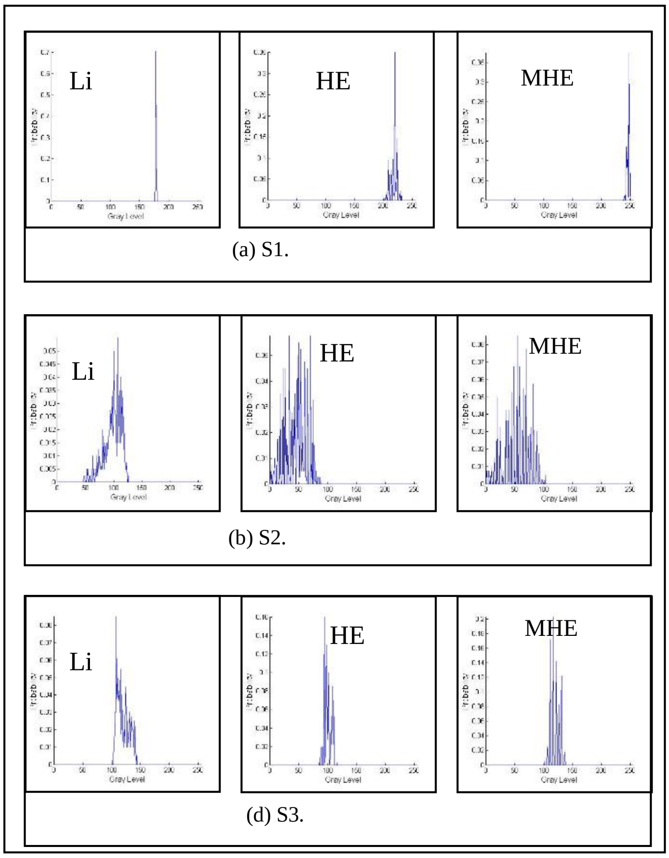


Fig. (10) Select regions in images (I) enhanced by algorithms: Li., HE and MHE.

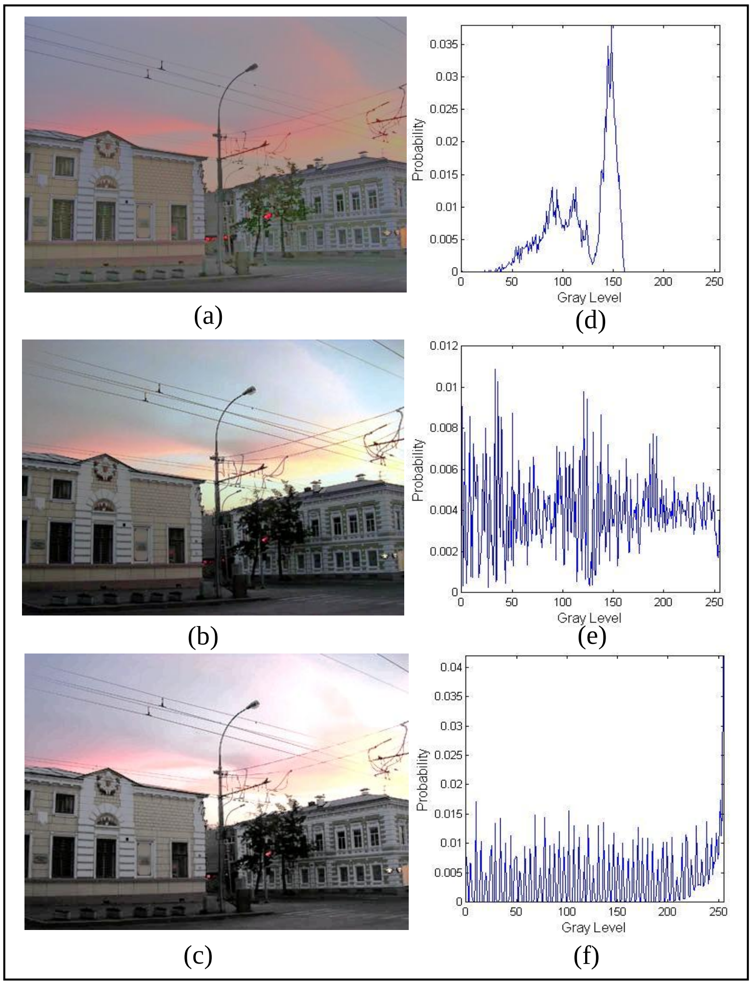


Fig. (11) The results of the enhanced image (II) and its histogram using Li, HE and MHE respectively.

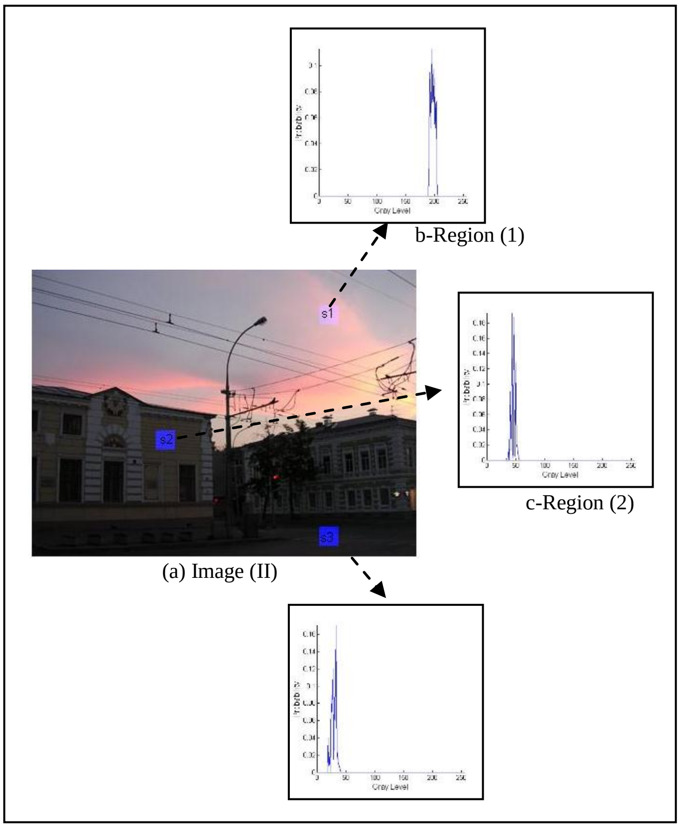


Fig.(12) Positions of select regions and its histograms in images (II) .

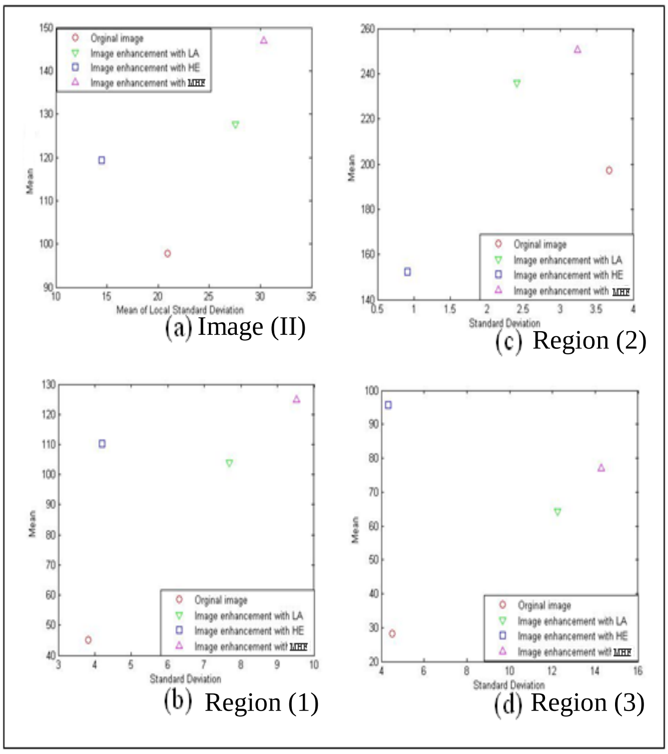
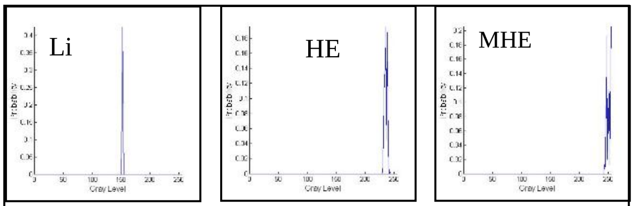
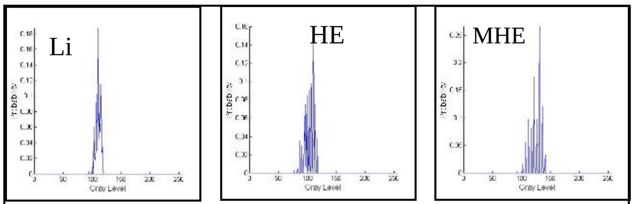


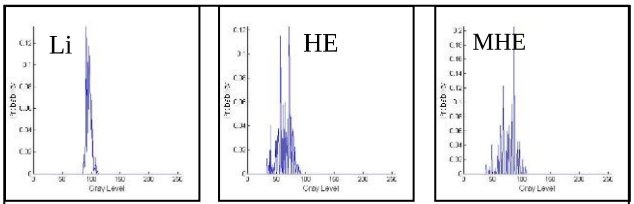
Fig.(13) Relationship between mean of local standard deviations and mean of image (II) and its select regions.



(a) S1.



(b) S2.



(d) S3.

Fig.(14) Select regions in images (II) enhanced by algorithms: Li., HE and MHE.

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[1٤] http://akvis.com(see in 2009).

الخلاصة

في هذا البحث تم تحسين الصور الملونة ذات المناطق القاتمة باستخدام خوارزمية تسوية الهستوغرام المقترحة AHE هذه التقنية تعالج مركبة الاضاءة في فضاء YIQ اللوني حيث تستخدم دالة السكمويد sigmiod function كتحويل لها ثم يطبق عليها تسوية الهستوغرام الاعتيادية. العلاقة بين المعدل ومعدل الانحراف المعياري والمخططات التكرارية تم حسابها لمعرفة كفاءة هذه الطريقة حيث قورنت مع خوارزمية AINDANE وكذلك مع خوارزمية تسوية الهستوغرام الاعتيادية، جميع هذه الخوارزميات انجزت باستخدام برنامج Matlab 7، اظهرت الخوارزمية المقترحة تحسين افضل من بقية الخوارزميات.