An Adaptive Approach for image Enhancement and Naturalness Preservation

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Abstract—Image enhancement simply means getting a clearer image, that is to process an image so that the result is more suitable than the original image for specific applications. The enhancement process does not increase the inherent information content in the data. But it does increase the dynamic range of the chosen features so that they can be detect easily. Image enhancement and Naturalness preservation plays an important role in image processing and analysis. Naturalness preservation while enhancing the details of an image is very essential to maintain a good perceptual quality. Many algorithms are available for image enhancement. This paper proposes an adaptive method for naturalness preservation and image enhancement. Image Enhancement using bi-log transformation and differential intensity histogram equalization are adaptively adopted to get the best results. First, a brightpass filter is defined to decompose the image into reflectance and illumination. The illumination image is processed and synthesis with reflectance image to obtain the enhanced image. Illumination image can be processed either by using bi-log transformation or differential intensity histogram equalization. Depending upon the cumulative density function of the illumination image, this method adaptively chooses bi-log transformation or histogram equalization for image enhancement. Lightness order error(LOE) is used to measure the naturalness preservation objectively. Lower the LOE value, better the naturalness preserved.

Keywords- *Bi-log transformation, Bright-pass filter, image enhancement, lightness order error, naturalness, DIH*

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I. INTRODUCTION

Image enhancement has an important role in the image processing applications. The objective of image enhancement is to make an image clearly recognized for a specific application. Image enhancement simply means getting a clearer image, that is to process an image so that the result is more suitable than the original image for specific applications. It refers to accentuation, or sharpening, of image features such as edges, boundaries, or contrast to make a graphic display more useful for display and analysis. The enhancement process does not increase the inherent information content in the data. But it does increase the dynamic range of the chosen features so that they can be detect easily. Image enhancement is mainly used in different areas of science and engineering such as atmospheric sciences, astrophotography, medical image analysis, analysis of image from satellites etc. Naturalness preservation while enhancing the details of an image is very essential to maintain good perceptual quality.

Image enhancement process consists of a collection of techniques that seek to improve the visual appearance of an image. The basic aim of enhancement is to make the image look better. The image enhancement techniques can be broadly divided into two such as spatial domain methods and frequency domain methods. Spatial domain techniques directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain techniques, the image is first transferred into frequency domain. That is the fourier transform of the image is computed first and all the enhancement operations are performed on the fourier transform of the image. Finally the inverse fourier transform is calculated to obtain the resultant image.

Most of the image enhancement algorithm focuses on detail enhancement of the image which may cause unnatural looks. Sometimes these kind of algorithms results in over-enhancement. So it is essential for an image enhancement algorithm to make a proper balance between the details and the naturalness of an image.

Naturalness is essential for image enhancement to achieve pleasing perceptual quality. Image enhancement has been applied to varied areas of science and engineering, such as atmospheric sciences, astrophotography, biomedicine, computer vision, etc. Many image enhancement algorithms, such as the Retinex based algorithms, the unsharp masking algorithms, the histogram equalization (HE) algorithms etc., have been proposed. Part of the algorithms focus on detail enhancement, but usually result in unnatural looks, such as light source confusion and artifacts. Hence, some others attempt to reduce over-enhancement at the cost of details.

Recently, some natural enhancement algorithms based on Retinex theory are proposed to enhance details with the naturalness preserved. However, these algorithms are not suitable for non-uniform illumination images.

In order to preserve the naturalness as well as enhance details for all non uniform illumination images, this paper proposes an adaptive method which uses two types of transformation adaptevely. Firstly, a brightpass filter is designed to decompose the image into reflectance and illumination. Secondly, the illumination image is processed using either bi-log transformation or differential intensity histogram equalization depending upon the proposed cumulative density function of the illumination image. Finally, the lightness order error (LOE) is calculated using the proposed method to get the naturalness preservation objectively. Experimental results demonstrate that the proposed algorithm can achieve appropriate results on all kind of non-uniform illumination images.

The remainder of this paper is organized as follows. The next section presents the performance measure of naturalness preservation. The third section describes the technique details of the proposed enhancement algorithm, including the bright-pass filter, the bi-log transformation and the differential intesity histogram equalization. The experimental results conducted for different images present in Section IV. Finally, the paper is concluded in Section V.

II. LIGHTNESS ORDER ERROR MEASUREMENT

The naturalness of an enhanced image is related to the relative order of lightness in different local areas. Therefore, the quantitative LOE measure based on the lightness order error between the original image *I* and its enhanced version *I*e[1]. The lightness *L(x, y)* of an image is given as the maximum of its three color channels:

$$L_{(x,y)} = max_{c\epsilon[r,g,b]} I^c(x,y) \quad (1)$$

For each pixel *(x, y)*, the relative order difference of the lightness between the original image *I* and its enhanced version *I*e is defined as follows:

$$RD_{(x,y)} = \sum_{i=1}^{m}\sum_{j=1}^{n}\Big(U\big(L(x,y),L(i,j)\big) \oplus U\big(L_e(x,y),L_e(i.j)\big)\Big) \quad (2)$$

$$U(x,y) = \begin{cases} 1, & for x > y \\ 0\,, & else \end{cases} \quad (3)$$

where *m* and *n* are the height and the width, *U(x, y)* is the unit step function, ⊕is the exclusive-or operator. The LOE measure is defined as:

$$LOE = \frac{1}{m*n}\sum_{i=1}^{m}\sum_{j=1}^{n} RD(i,j) \quad (4)$$

From the definition of LOE, we can see that the smaller the LOE value is, the better the lightness order is preserved. In order to reduce the computational complexity, we take the down-sampled versions *DL* and *DL*e of size *dm* × *dn* instead of *L* and *L*e. The ratio *r* between the size of the downsampled image and that of the original images is set as *r* = 50/ min*(m, n)*. As a result, the size *dm* × *dn* of the down sampled image is [*m* · *r*] × [*n* · *r*].

III. THE PROPOSED ALGORITHM

In this section, we present the technique details of the proposed enhancement algorithm which includes five parts. Firstly, the original image is decomposed into reflectance and illumination through the bright-pass filter. Secondly, the cumulative density function of the illumination image is analyzed. Then, depending upon the CDF of the illumination image, that image is processed using either bi-log transformation or differential intensity histogram equalization. Finally, the enhanced image is obtained by synthesizing the reflectance and the processed illumination.

A. Design of brightpass filter

The range of reflectance in an image is very important to maintain the naturalness and details. If the range of reflectance is not in between 0 and 1, which results over-enhancement. Therefore, it is essential for an image enhancement algorithm to maintain the range of reflectance in between 0 and 1. The bright-pass filter defined in this method is able to restrict the reflectance to 0 and 1. The basic idea of bright-pass filter is that, the effect of a pixel to its neighboring pixel is positively related to frequency of the pixels having the same value all over the image.

The neighbors of each pixel in the selected image are considered in the further processing. The effect of a pixel to its neighboring pixel is considered as the same all over the image having same values. Similarly, the effect of a pixel to its neighboring pixel is considered to be positively related to the frequency of pixels all over the image. Here, the frequency of pixels means, the repeating combinations of pixels having the same values all over the image.

For a pixel G(x,y), the neighbors of this pixel in a five pixel square four pixel connectivity can be obtained as,

$$NB(x,y)=\{G(x,y-1),G(x,y+1),G(x-1,G(x+1,y),G(x,y)\} \quad (5)$$

For the pixel of value k at (x,y), $NN_{k,l}(x,y)$ indicates the number of neighbors of value l. So the frequency Q'(k,l) for pixels of values k and l to be neighbors all over the image can be expressed as,

$$Q'(k,l) = \sum_{x=1}^{m}\sum_{y=1}^{n} NNk,l(x,y) \quad (6)$$

where m and n are the height and the width of the image.

In digital signals, the frequency Q'(k,l) is prone to suffer from noise and varies continuously. In order to avoid the noise from the digital signals, the local mean Q(k,l) in used instead of Q'(k,l) and Q(k,l) can be expressed as,

$$Q(k,l) = \Big(\sum_{i=l-win}^{i=l+win} Q'(k,l)\Big)/(2*win)$$

where win is the window size. In order to preserve the local trend of the frequency, the window size(win)should not be too small or too large. So the window size is empirically set as,

$$win = floor(max(G(x,y)) - min(G(x,y)))/32) \quad (7)$$

The bright-pass filter is used to decompose the original image into reflectance image and illumination image. Normally, the illumination image is refined through the bright-pass filter and separating the illumination image from the original image gives the reflectance image. The bright-pass is the weighted average of the adjacent pixels with the weight positively related to the frequency Q(k,l) as,

$$BPF[G(x,y)] = \frac{1}{W(x,y)}\sum_{(i,j\epsilon\Omega)}\Big(Q\big(G(x,y),G(i,j)\big).U\big(G(x,y),G(i,j)\big).G(i,j)\Big) \quad (8)$$

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where Ω denotes the local patch centered at co-ordinates (x,y). U(x,y) indicates the unit step function used to ensures that only brighter are taken into consideration, the normalization factor W(x,y) ensures the sum of pixel weight to be 1.

$$W(x,y) = \sum_{(i,j\epsilon\,\Omega)} \Big(Q\big(G(x,y),G(i,j)\big).U\big(G(x,y),G(i,j)\big)\Big)$$

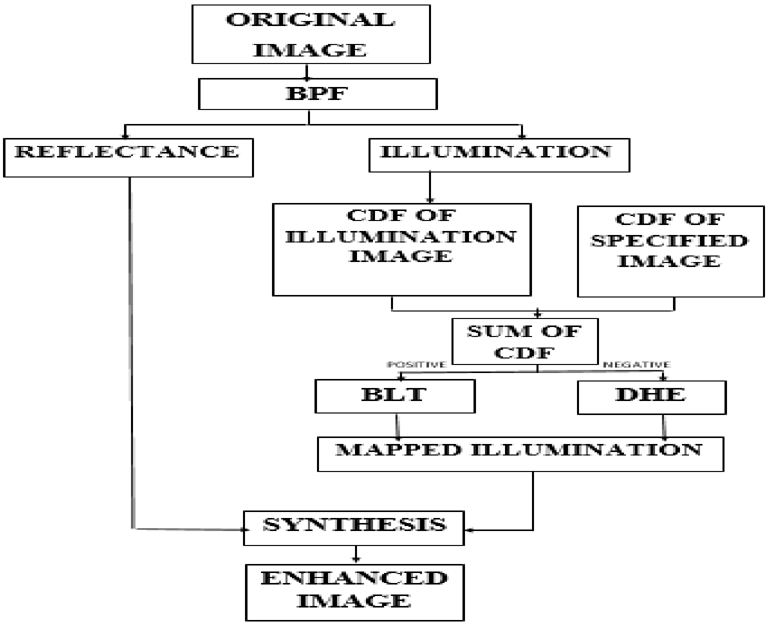


Fig 1. Block Diagram of the Proposed algorithm

B. Image Decomposition Using the Bright-Pass Filter

According to retinex based algorithm, the reflex lightness of an image is defined as the product of reflectance and illumination. That is,

$$I^c(x,y)=R^c(x,y)\cdot F(x,y) \qquad (9)$$

where $I^c(x,y)$ is the original image lightness of the colour channel c. $R^c(x,y)$is the reflectance of the image and F(x,y) is the illumination of the original image. The reflectance of the image represents the local details of an image and the illumination indicates the light cast on the surface.

The illumination image can be separated from the original image by using any kind of proper filters like guassian filter or bilateral filter. These type of filtering usually causes the illumination to be darker than the reflex lightness. That unreasonably means the reflectance is more than 1. If the reflectance is more than one, that indicates the surface reflects more light than it receives.

The bright-pass filter is designed based on the assumption that the illumination is the local maxima for each pixel. Unlike traditional filters, the bright-pass filter designed here considers only brighter neighbors that brighter than the central pixel into account. Compared with darker areas, it is obvious that brighter areas are closer to illumination.

The bright-pass filter is designed on the assumption that the three colour channels have the same illumination. The illumination image can be refine through the bright-pass filter as,

$$L_r(x,y) = \frac{1}{W(x,y)} \sum_{(i,j\epsilon\,\Omega)} \left(\begin{array}{c} Q\big(L(x,y),L(i,j)\big)\,. \\ U\big(L(i,j)\big),L(x,y).L(i,j) \end{array}\right) \qquad (10)$$

Where L(x,y) is the image lightness which is the maximum of the original image's three colour channels. That is,

Then, the reflectance image can be obtained by removing illumination image from the original image.

$$R^c(x,y) = \frac{I^c(x,y)}{L_r(x,y)} \qquad (11)$$

(a) (b) (c)

Fig 2: Decomposition using brightpass filter (a)Original image (b)Illumination Image (c)Reflectance Image

C.Definition of Cumulative Density Function

According to the definition of the Cumulative Density Functions (CDF) , the CDF of the weighted histogram is:

$$cL(v) = \sum_{k=0}^{v} mp(k) = \frac{\sum_{i=0}^{m}\sum_{j=0}^{n} L_{1g}(i,j)\,.\,U(v,L_r(i,j))}{\sum_{i=0}^{m}\sum_{j=0}^{n} L_{1g}(i,j)} \quad (12)$$

where,

$$L_{1g}(x,y) = \log(L_r(x,y) + \epsilon),$$

$$mp(k) = \frac{\sum_{i=0}^{m}\sum_{j=0}^{n} L_{1g}(i,j)\,.\,\delta(L_r(i,j),k)}{\sum_{i=0}^{m}\sum_{j=0}^{n} L_{1g}(i,j)}$$

$$\delta(x,y) = \begin{cases} 1, & for x = y \\ 0\,, & else \end{cases}$$

where, *mp(k)* is the weighted histogram, δ is the impulsive function,ϵ small positive constant and is empirically set as 1.

Similarly, the CDF of the specified histogram, *s(z)*, is defined as follows:

$$cf(z) = \sum_{i=0}^{z} s(i) \Big/ \sum_{i=0}^{255} s(i) \qquad (13)$$

$$s(z) = \log(z+\epsilon)\,,\ \ z \epsilon N[0{,}255]$$

where *z* is a non-negative integer within [0, 255], ε is a small positive constant.

$$D(v,z) = \sum_{v=0}^{255}\sum_{z=0}^{255} cL(v) - cf(z) \qquad (14)$$

For all the positive values of D(v,z), the illumination is mapped using bi-log transformation and for all the negative values of D(v,z), the illumination is mapped using differential intensity histogram equalization.

D. Illumination Mapping Using Bi-Log Transformation

After separating the illumination image and reflectance image from the original image, the reflectance image is kept as it is and the illumination image is mapped using bi-log transformation. The final enhanced image is obtained by synthesizing the mapped illumination and reflectance image. Synthesis of mapped illumination and reflectance should not suppress the details so that it should be bright enough and the lightness order should be preserved.

According to the definition of histogram specification, the purpose of BLT is to seek values of *z* that satisfies:

$$cf(z_v) = cL(v), \quad for\ v = 0,1,2, \ldots\ldots, L-1 \qquad (15)$$

The values of $z_v$is given by,

$$z_v = cf^{-1}[cL(v)], \quad forv = 0,1,2, \ldots\ldots, L-1 \qquad (16)$$

The mapped illumination can be obtained through the BLT transformation.

$$L_m(x,y) = cf^{-1}[cL(L_r(x,y))], \quad forv = 0,1,2, \ldots\ldots, L-1$$

E. Differential Intensity Gray-Levels Histogram Equalization (DIHE)

Consider an input image *f*(*i*,*j*), which is a the total number of *N* pixels with gray-levels in the range [0, *L*-1][10]. We calculate thedifferential gray-levels of the input image as follows:

$$d(i,j) = int\left\{\sqrt{d_H(i,j)^2 + d_V(i,j)^2}\right\} \qquad (17)$$

where

$$d_H(i,j) = \{f(i+1,j+1) + 2.f(i+1,j) + f(i+1,j-1)\} - \{f(i-1,j+1) + 2.f(i-1,j) + f(i-1,j-1)\}$$

$$d_V(i,j) = \{f(i+1,j+1) + 2.f(i,j+1) + f(i-1,j+1)\} - \{f(i+1,j-1) + 2.f(i,j-1) + f(i-1,j-1)\}$$

int{} in Eq.(15) represents the integer transform processing.

The differential gray-level histogram (DH) $h_d(r)$ is given by

$$h_d(r) = \sum_{(i,j)\epsilon D_r} d(i,j) \qquad (18)$$

where *D*r is a region composed of pixels whose value is *r*. Thus, the horizontal axis of DH is gray-level *r* and the vertical axis is the total differential gray-levels of (*i*,*j*) points which meet the condition *f*(*i*,*j*)=*r*.

The DH equalization (DHE) will map an input gray level *r* into an output gray level *s* using the following transformationfunction *T*(*r*).

$$s = T(r) = (L-1).c(r) \qquad (19)$$

where

$$c(r) = \frac{\sum_{k=0}^{r} h_d(k)}{\sum_{k=0}^{L-1} h_d(k)} \qquad (20)$$

The differential intensity gray-level $d_I(i,j)$ is given by replacing *f*(*i*,*j*) with $I_{in}(i,j)$ in Eq.(15). The DIH $h_d^{I(i,j)}(r)$ is also given using $d_I(i,j)$ instead of *d*(*i*,*j*) in Eq.(16). The transfer function of the DIHE is derived by using $h_d^{I(i,j)}(r)$ same way of Eq.(17). *$I_{in}(i,j)$ is the intensity component of the illumination image.*

F. Synthesis of Reflectance and Mapped Illumination

As mentioned above, the drastic variation of illumination is disadvantageous to the display of details, but illumination is essential for naturalness preservation. In order to enhance details and preserve naturalness, the mapped illumination is taken into consideration.

Final enhanced image can be obtained by multiplying the mapped illumination with the reflectance.

IV. COMPARISON OF EXISTING & PROPOSED SYSTEM

If the images with sum of the difference in cumulative density function of the original illumination image and the cumulative density function of the reference image is negative, the existing method will cause flickering at the output. In the new method such images are processed by using an another method that is differential intensity histogram equalization. This method first analyzes the CDF of the illumination imagea and according to the CDF, it adaptively chooses either bi-log transformation or differential intensity histogram equalization. Comparison is shown in Table I.

V. EXPERIMENTS AND RESULTS

Compared to the existing algorithms, the proposed algorithm can not only enhance the details, but also maintains the naturalness for the non-uniform illumination images. The proposed algorithm can achieve good quality from both subjective aspect and objective aspect.

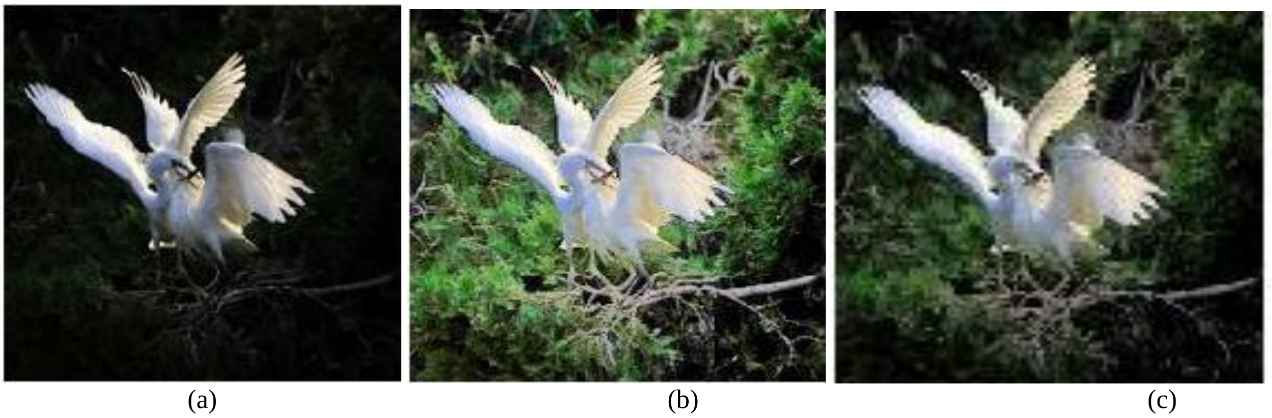
Table I demonstrates the selection and performance of the proposed method. The lightness order error is calculated after the synthesis of the illumination image with the reflectance image. Lower the LOE value, better the naturalness preserved. The experimental result shows that the bi-log transformation and the differential intensity histogram equalization gives good results than all other existing method.

TABLE I
RESULTS OF ADAPTIVE ENHANCEMENT METHOD

IMAGE	CDF DIFFERENCE	METHOD	LOE
Birds	80.06	BLT	2
Harbor	26.13	BLT	0.25
Rail	-20.55	DIHE	0.5
Church	-22.78	DIHE	0.625
River	39.89	BLT	0.25
Night fall	-31.46	DIHE	0.125
Parking	43.56	BLT	0.125
skyscraper	39.39	BLT	0.75
City	-6.86	DIHE	0.375

(a) (b) (c)

Fig 3. Result obtained using (b)DIHE (c)BLT, in this image better enhancement for the original image(a) is provided by DIHE



(a) (b) (c)

Fig 4. Result obtained using (b)BLT (c)DIHE, in this image better enhancement for the original image(a) is provided by BLT

VI. CONCLUSION

This paper proposes an adaptive approach for image enhancement and naturalness preservation, which provides better results than all other existing image enhancement techniques. In this method, according to the sum of the difference in cumulative density function between the illumination image and the specified histogram D(v,z), the illumination mapping is performed by either bi-log transformation (BLT) or differential intensity histogram equalization (DIHE). Since, this method adaptively chooses BLT or DIHE for illumination mapping, it is very useful for all kind of images. Here, Lightness Order Error (LOE) is used to measure the naturalness preservation objectively. Lower the LOE values, better the naturalness preserved. This method can be effectively applied for video enhancement also. This will be our future work.

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