International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Assessment Of Color Normalization Algorithms Under Various Illuminations

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Abstract*: Contrast enrichment is an essential area in the field of digital image handling for human visual perception and computer vision. Digital images have become a part of our everyday life and imaging devices are everywhere, from higher end digital cameras to video cameras integrated in laptops or cell phones. Images of a scenery taken with a number of cameras will possess diverse values of color owing to the deviations in reproducing color through various devices. Humans are likely to neglect the illumination while adjudicating the appearance of an entity. However the same does not hold true for various image capturing devices where the same object will often look different under different illuminations. The goal of the computational color normalization is to account for the result of the illuminate. This paper aims at simulating and comparing few of the color normalization algorithms like Histogram Equalization, Gamma correction and White patch Retinex using MATLAB image processing toolbox and a few statistical parameters related to the processed image are found. The results indicated that the retinex algorithm performed better than the other algorithms and it could be a prospective area of research in the field of face recognition.

***Keywords* : Color normalization, Image processing, MATLAB, Histogram equalization**

I. INTRODUCTION

Color normalization is a process that evaluates the control of dissimilar illumination sources on a digital image. The prime objective of any color normalization algorithms include achievement of complete modification of the intensity of color in an image, so as to enable the replicated image to acquire the right color features of any entity. It is witnessed that these algorithms are applicable in areas ranging from digital photography to machine vision, and from recognition of object to situations where the color of an entity could be vital in attaining a portrayal of an object. Generally the allotment of color values in an image depends on the illumination, which may differ depending on different lighting environments or cameras. The same scene viewed under two different illuminants introduces two different color images. Even if the illuminants are of the same color but are placed at different positions and if the lighting geometry is fixed and color of the light source is changed, image looks different. Color normalization is a technique that aims to produce a description of an image that is invariant to the illumination conditions under which the image was taken [1].

Numerous algorithms exist for accomplishing color normalization [2], [3] and this paper focuses on presenting only a limited number of these algorithms. It is worth noting that the success of application of an algorithm relies on the task. An algorithm that does well in one of the tasks might not perform the same way in some other task. Therefore, the selection of an algorithm rests on the likings of the user for the concluding result.

Manuscript published on 30 September 2019.
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II. COLOR NORMALIZATION ALGORITHMS

A. *Histogram Equalization*

Histogram equalization is the process of varying an image by adjusting its histogram. The common application of this process covers normalization by which it is possible to create flat image histogram [4]. Histograms are quite easy to compute in software and offer themselves to cost-effective execution in hardware. This enables it to become a widely used tool in real-time image processing. It is widely used for image processing in medical areas and also as a pre-processing phase in areas of recognition of speech, synthesis of texture and several applications involving image or video processing.

Histogram Equalization [5] permits regions of lesser contrast to advance to a greater contrast and spontaneously evaluates a transformation function in quest of yielding an image having uniform histogram as the output. The summation of all constituents of a normalized histogram is unity. The histogram of digital image having intensity level ranging from $[X_0, X_{L-1}]$ is a discrete function. Histogram Equalization is a structure that plots the input image into the total dynamic range $[X_0, X_{L-1}]$ making use of the cumulative distribution function as a transform function. This technique is beneficial for both bright or dark images.

$$h(r_k) = n_k \tag{1}$$

where, r_k is the value of the intensity; n_k is the pixel number of an image having an intensity r_k and $h(r_k)$ is the histogram of an image having gray level r_k.

Histograms are commonly normalized by the total pixel numbers in an image. Supposing there is an image of M x N, a normalized histogram is given by the expression,

$$P(r_k) = n_k/MN;\ k=0,1,2,3\ldots\ldots\ldots\ldots(L-1) \tag{2}$$

where $P(r_k)$ provides an approximation of the probability with which a gray level r_k occurs.

Let $X=\{X(i,j)\}$ denote an image comprising of L distinct gray levels given by,

$X=X_0, X_1\ldots\ldots\ldots\ldots\ldots\ldots\ldots X_{L-1}$ for a specified image X; the probability density function is expressed as,

$$P(X_k)= n^k/n \tag{3}$$

where, k=0,1,……L-1; n^k is the total samples in an input image; $P(X_k)$ is associated with histogram of the specified image which represents the pixel number which possesses an intensity X_k.

Based on the probability density function, the cumulative density function is defined as,

$c(x) = \Sigma p(X_j)$

where, j=0,1,....k; X_k =x for k=0,1……….(L−1)

$c(X_{L-1}) = 1$ by definition.

A transform function f(x) based on the cumulative density function defined as,

$$f(x) = (X_0 + X_{L-1} - X_0)c(x) \quad (4)$$

Then the output image of the Histogram Equalization, Y={Y(i,j) can be expressed as $Y=f(x)=f(\{x(i,j)/\forall X(i,j) \in X\}$. The same method is applied separately to the Red, Green and Blue (RGB) component of the color image.

Gamma Correction

Gamma correction illuminates dark spots in an image, thus allowing a more clear distinction of colors. Gamma correction is mainly used in cases where a dynamic range correction is necessary. The gamma correction method adjusts the magnitude of every color channel confirming the display would not be saturated. Also, the average value of every color channel is tuned to the average of the intensity of an image. This system conserves the information of intensity carried by the image regardless of the modification in magnitudes of color. To perform the Gamma correction, a reference to the intensity is done. Initially, the RGB image is transformed to the Hue-Saturation-Intensity (HSI) color space where the intensity of the image is specified by the I-channel as a gray level image [6], [7]. In other words,

$$HSI \leftarrow RGB,\ I = (R + G + B)/3 \quad (5)$$

The average value of the I-component is represented as the reference and all color channels namely R, G and B need to be tuned to this value. Since the resultant of the average value of each color channels are equal, their gray equivalent will be in compromise with the original image. With the aim of providing acceptable color adjusted images, a non linear scaling scheme called as the Gamma correction method is implemented.

Consider a color channel, for instance, the red channel with the generally used range of magnitude $R^{\wedge(norm)}$ =[0,1]. This amount is normalized so that Gamma=$R^{\wedge(Gamma)}$. At this time the normalized amount is raised to the power of Gamma, that is, since the extreme of $R_{(Gamma)}$ is restricted to unity, then $R^{\wedge(Gamma)}$ is also unity. Conversely, when $R_{(Gamma)}$ =0, the magnitude of the Gamma corrected image is also zero. Hence, the range [0, 1] is preserved while the mean magnitude is altered in agreement with particular values of the parameter. The same process is repeated for the other two color channels [8].

B. *White Patch Retinex*

Retinex algorithm depends on possessing a bright area of intensity at some place in the image. If there exists a white area in the image, then it redirects the maximum light possible for every band. If linear relationship is assumed between the sensor response and the colors of the pixel, then the light illuminating the area magnifies by amount equal to the product of the Geometry term (G) and the Reflectance (R_i) of the entity. The Retinex theory [9] is based on the assumption that the presence of a white patch anywhere in the scene reflects the maximum intensity of light possible for each band. Once a bright patch has been located, its colour value can be used for an estimate of the white patch. Practically, instead of looking for a bright patch (or white patch) one determines the maximum of each band over all pixels. This theory is based on the observation that the light incident on a white patch is unchanged after reflection. Additionally, a white reflectance must induce maximal camera responses. For each of the color channels find intensity I_i; where i ={1,2,3} for R, G and B.

For the Retinex, the centre is basically each value of the pixel and the surround happens to be a Gaussian function. The mathematical formula of Retinex [10] is expressed by the following equation,

$$R(x,y)=Log[I(x,y)]-Log[I(x,y)*F(x,y)] \quad (6)$$

where, I is the input; R is the output image as obtained by Retinex and F is the Gaussian filter (surround or kernel) which is given by the expression,

$$F(x,y)=Ke^{[-(x^\wedge 2+y^\wedge 2)/\sigma^\wedge 2]} \quad (7)$$

where, σ is the standard deviation of the filter, and K is a normalization factor which preserves the area under the Gaussian curve.

III. RESULTANT IMAGES UNDER VARIOUS ILLUMINATIONS

The figures from Fig. 1 to Fig. 3 show the sample input image taken under various illuminations like bright light, dark light, low and high contrast illuminations and their corresponding resultant images after the application of Histogram Equalization, Gamma correction (for Gamma <1) and White patch retinex.

Fig. 1. Temple image under various light illuminations: a) direct sunlight b) indirect sunlight c) High contrast d) Low

Retrieval Number: K12910981119/19©BEIESP
DOI: 10.35940/ijitee.K1291.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Fig. 2. Temple image under various light illuminations: a) direct sunlight b) indirect sunlight c) High contrast d) Low contrast. The resultant Gamma corrected images are shown in Figure (i) to (l) respectively.

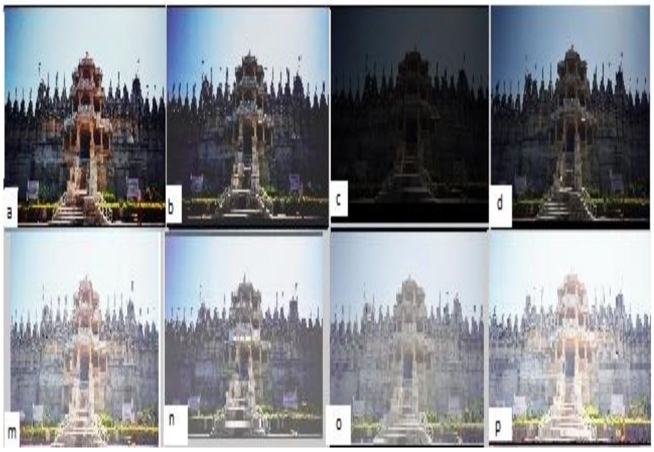

Fig. 3. Temple image under various light illuminations: a) direct sunlight b) indirect sunlight c) High contrast d) Low contrast. The resultant White Patch Retinex images are shown in Figure (m) to (p) respectively.

IV. PERFORMANCE EVALUATION

A comparison between the different color normalization algorithms is done as shown in Table I to Table IV based on the parameters namely, Normalized Absolute Error (N.A.E.), Normalized Cross Correlation (N.C.C.) and Peak Signal to Noise Ratio (P.S.N.R.). The performance of an algorithm is evaluated based on the PSNR value being maximum, NAE being minimum and NCC being nearly equal to unity.

Table- I: Under bright illumination

Parameter	Algorithms		
	Histogram Equalization	*Gamma < 1*	*White Patch Retinex*
PSNR	32.4557	32.4635	99
NAE	0.9955	0.9937	0.7397
NCC	0.0041	0.0050	1.3317

Table- II: Under dark illumination

Parameter	Algorithms		
	Histogram Equalization	*Gamma < 1*	*White Patch Retinex*
PSNR	32.4963	32.5015	99
NAE	0.9954	0.9942	0.4353
NCC	0.0043	0.0049	1.2531

Table- III: Under high contrast

Parameter	Algorithms		
	Histogram Equalization	*Gamma < 1*	*White Patch Retinex*
PSNR	39.1869	39.2006	99
NAE	0.9798	0.9755	5.4463
NCC	0.0179	0.0190	5.0104

Table- IV: Under low contrast

Parameter	Algorithms		
	Histogram Equalization	*Gamma < 1*	*White Patch Retinex*
PSNR	34.0833	34.0915	99
NAE	0.9935	0.9916	1.3865
NCC	0.0059	0.0065	1.7911

As mentioned previously, the larger the PSNR value, the more efficient the method is. The results obtained indicate that the PSNR is very high for White Patch Retinex algorithm compared to all other algorithms. NAE is found to be minimum in two cases and NCC is nearly equal to unity for images under various illuminations. Visual difference is also less in case of White Patch Retinex when compared to all other algorithms.

V. CONCLUSION

Even though a vast number of color constancy algorithms are present, the performance of each algorithm depends on the task. The effectiveness and choice of the algorithm depends on the different lightning conditions, surrounding environment and finally the personal preference. In this work algorithms like Histogram Equalization, Gamma correction and White patch Retinex were applied on sample images taken under different lighting conditions. The image processing toolbox of MATLAB was used to visualize the processed image and determine some of the useful statistical data to assess the image quality. By far, the white patch retinex is found to be the best algorithm under various lighting conditions since its high PSNR value makes it efficient.

ACKNOWLEDGMENT

The author expresses sincere thanks to all those involved directly or indirectly in contributing for this article.

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