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LUMA Based Histogram for Image Enhancement

K Madhavi
Department of Electronics & Communication Engineering
Siddhartha Institute Of Technology & Sciences

A. Srinivas Reddy
Department of Electronics & Communication Engineering
Siddhartha Institute Of Technology & Sciences

Abstract—**A luminance based multi scale retinex (LB_MSRCR) algorithm for the enhancement of darker images is proposed in this paper. The new technique consists only the addition of the convolution results of 3 different scales. In this way, the color noise in the shadow/dark areas can be suppressed and the convolutions with different scales can be calculated simultaneously to save CPU time. Color saturation adjustment for producing more natural colors is implemented. Each spectral band can be adjusted based on the enhancement of the intensity of the band and by using a color saturation parameter. The color saturation degree can be automatically adjusted according to different types of images by compensating the original color saturation in each band. Luminance control is applied to prevent the unwanted luminance drop at the uniform luminance areas by automatically detecting the luminance drop and keeping the luminance up to certain level that is evaluated from the original image. Down-sized convolution is used for fast processing and then the result is re-sized back to the original size. Performance of the new enhancement algorithm is tested in various images captured at different lighting conditions. It is observed that the new technique outperforms the conventional MSRCR technique in terms of the quality of the enhanced images and computational speed.**

Index Terms— ***MSR, SSR, MSRCR, HISTOGRAM, COLOR CONSTANCY.***

I. Introduction

Standard image enhancement techniques modify the image by using techniques such as histogram equalization, specification etc. [1] so that the enhanced image is more pleasing to the visual system of the user than the original image. There is a difference between the way our visual system perceives a scene when observed directly and in the way a digital camera captures the scene. Our eyes can perceive the colour of an object irrespective of the illuminate source. But the colour of the captured image depends on the lighting conditions at the scene. Our aim is to enhance the quality of the recorded mage as to how a human being would have perceived the scene. This property that we aim to achieve is called 'colour constancy'. This property cannot be achieved using standard image enhancement techniques. Histogram equalization is basically a contrast enhancement technique that works well on images that are uni-modal (i.e. very dark or bright images). Advanced variants of histogram equalisation like Adaptive Histogram Equalisation (AHE) [2], Contrast Limiting Adaptive Histogram Equalisation (CLAHE)[3], Multi Scale Adaptive Histogram Equalisation (MAHE)[4] give strong contrast enhancement. But these methods are not used in colour image processing as strong contrast enhancement, might make the image look unnatural. One of the enhancement techniques that try to achieve color constancy is retinex (Retina+Cortex) [5].

A colour constancy algorithm must be able to simultaneously achieve the 3 properties given below [6],

1. Dynamic range compression,
2. Color independence from the spectral distribution of the scene illuminate and,
3. Color and lightness rendition.

The first property can be achieved by applying logarithmic transformations on the image [1]. The second property can be achieved by eliminating the illuminance component in the image. Every pixel in an image can be represented as a product of luminance and reflectance i.e.

$$S(x, y) = R(x, y) * L(x, y) \quad (1)$$

Where L represents illuminance, R represents reflectance and S represents the image pixel. Our aim is to eliminate L(x, y). Illumination varies slowly across the image unlike reflectance. So illuminance of an image can be obtained by low pass filtering the image .Instead of obtaining R = S/L, we use logarithmic approach to achieve the same, since applying logarithm on an image gives us dynamic range compression. Let s = log(S), r1 =log(R), l = log (L). So now equation 1 can be represented as,

$$r1(x, y) = s(x, y) - l(x, y) \quad (2)$$

L can be obtained by convolving a low pass filter F with image S. Initially Land proposed [5] 1/r2 as the low pass filter F, where r =√(x2 + y2), x and y are the pixel locations. By using this function, the first 2 properties of color constancy were achieved but not the third one. Zia etal. [6], proposed a new method popularly known as Single Scale Retinex(SSR) to overcome this problem.

In this paper we will look at the SSR algorithm in SectionII, a modified version of SSR named as Multi Scale Retinex (MSR) in Section III, a variant of MSR known as Multi Scale Retinex with Color Restoration (MSRCR) in Section IV and finally we present our histogram approach to LUMA BASED MSRCR in section V.

II Single Scale Retinex (SSR)

Mathematically, Retinex equation can be represented as,

$$Ri(x, y) = \log [Ii(x, y)] - \log [F(x, y) * Ii(x, y)] \quad (3)$$

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Where Ii(x, y) is the image distribution in the ith color Spectral band, '*' denotes the convolution operation, F(x, y) is the surround function and Ri(x, y) is the associated retinex output. The problem with Land's model can be overcome by using a Gaussian surround function as given in the equation below,

$$F(x, y) = e^{-r2/c2} \quad (4)$$

The retinex operation is performed on each spectral band. For the Gaussian surround function, when the surround constant is varied from a small value to a large value, dynamic range compression is sacrificed for improved rendition. The middle of the range (50 < c < 100 pixels) represents a reasonable compromise, where shadows are fairly compensated and rendition achieves acceptable levels of image quality [6]. To compensate for this disadvantage of single scale retinex i.e. it can either achieve good dynamic range compression or good color rendition, we go for multi scale retinex method which helps us to achieve both simultaneously.

III: MULTI SCALE RETINEX (MSR)

In the multi scale retinex method [7], we find the retinex output according to equation 5 for various values of surround constants and add all the retinex outputs by giving them equal weight as,

$$RMSRi = \sum_{n=1}^{N} wnRni \quad (5)$$

Where N is the number of scales, Rni is the ith componentof the nth scale, RMSRi is the ith spectral component of theMSR output, and wn is the weight associated with the nth scale [7]. The only difference between R(x, y) and Rn(x, y)is that the surround function is given as,

$$Fn(x, y) = e^{\; r2/cn2} \quad (6)$$

Experimental results have shown that it is enough to usejust 3 scales viz. one small scale (cn < 20), one large scale (cn > 200) and third one as an intermediate scale value [6].The three different retinex outputs that we get because of using the gaussian surround function with three different scaling functions, is equi-weighed and added to get the final retinex output.

IV.MULTI SCALE RETINEX FOR COLOUR RESTORATION (MSRCR)

Retinex algorithm was originally developed for images that do not violate the 'grey-world' assumptions. If the reflectances of the image in all the three color bands are some on an average then the image is said to obey grey-world assumption. The general effect of retinex processing on images with regional or global grey-world violations is"greying out" of the image, either globally or in specific regions. This desaturation of color in some cases cans be severe. So we have to find a color restoration method that provides good color rendition for images that contain grey-world violations [7]. But one should be careful not to compromise on color constancy in our pursuit of color rendition, as color constancy is one of the prime objectives of retinex. The algorithm for color restoration is given below,

$$RMSRCRi(x, y) = G\,[Ci(x, y)RMSRi(x, y) + b] \quad (7)$$

Where

$$Ci(x, y) = f\,[Ii'(x, y)] \quad (8)$$

Is the ith band of the color restoration function (CRF) and RMSRCRi is the ith spectral band of the multi scale retinex with color restoration. The function that provides us the best overall color restoration is,

$$Ci(x, y) = \beta \log[\alpha Ii'(x, y)]$$

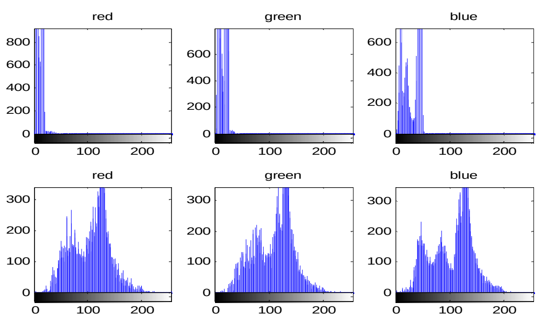
$$= \beta \log[\alpha Ii(x, y)] - \beta \log[\textstyle\sum_{i=1}^{S} Ii(x,y)] \quad (9)$$

Where β is a gain constant, α control the strength of the nonlinearity, G and b are final gain and offset values. The values specified for these constants by Zia et al. [6] are β = 46, α = 125, b = −30, G = 192.After performing color restoration it was found that the restored images were still "greyed-out". Though final gain and offset values, G and b, are used for the adjustment from logarithmic domain to display domain, "greying -out" Though final gainand offset values, G and b, are used for the adjustment from logarithmic domain to display domain, "greying -out "It was found that the "greying -out" of the image happens at the single scale retinex stage itself. So any treatment for this problem had to be applied at that stage. Ziaet al's paper on MSRCR [6] does not deal with this problem. But their earlier work on SSR [7] deals with this problem and recommends a histogram based approach. In Land's paper [5], this problem was not dealt with at all. Subsequently, Hulbert dealt with this problem in his Ph.D dissertation [8]. He proposed an automatic gain/offset approach, where the retinex values are adjusted by the absolute maximum and minimum found across all the values in all the color bands. But since this method could not give us a very good color rendition, we have used Zia et al.'s [7] canonical gain/offset method. The method actually results in clipping of some of the highest and lowest signal values, but it is not a problem since those regions carry very less information. Problem with this method is that the authors have not clearly specified how to choose the lower clipping and upper clipping point

V. LUMA BASED MSRCR

Though automated MSRCR performs well in most of the Cases, it fails to render exact colour when there are large Constant areas of constant colour. Applying MSRCR algorithm on the luma component of the image turned out to be a good solution for this problem. The PCA is the best transform from RGB space to luma and chroma space since the luma and chroma components are made to be completely independent(orthogonal) of each other. But PCA is not widely used since the transform is image dependent. The difference in the outputs obtained when MSRCR is applied only on the luma components that are obtained from different colour transforms. According to this paper, the outputs obtained after applying MSRCR on the luma components of YUV and Lab transforms is as close as the outputs obtained after applying

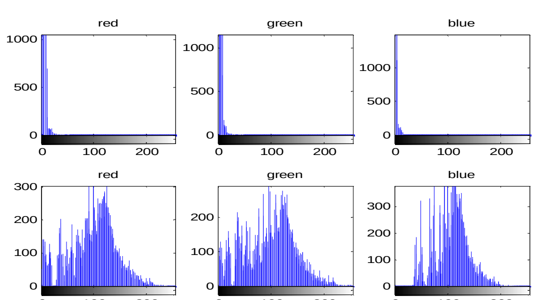
MSRCR on the luma component of PCA transform. The disadvantage of using the original MSRCR and how luma based MSRCR overcomes it. Even color rendition is better in luma based MSRCR for this particular example. Another advantage of luma based MSRCR is the simulation time is reduced approximately to one-thirds of the time it took for the original MSRCR since here the MSRCR algorithm is applied only on the luma component. One of the reasons for luma based MSRCR to give better results than original MSRCR is the automation step. Since the optimal value to automate the MSRCR algorithm was found using the trial and error procedure, a uniform optimal value of y = 0.05was used across all the three RGB colour bands. This might work for some images but need not necessarily work for all images. In luma based MSRCR approach, since the MSRCR algorithm (automated) is applied only on the luma channel, our automation algorithm is found to be more consistent across different images.



Histogram of luma based approach

Original image MSR image LUMA Based

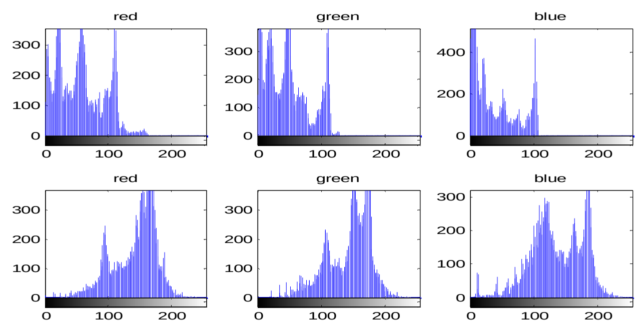
Fig. 1 Output of luma based approach



Histogram of luma based approach

Original image MSR image LUMA Based

Fig. 2 Output of luma based approach



Histogram of luma based approach

Original image MSR image LUMA Based

Fig. 3 Output of luma based approach

VI. Statistical Results

LUMA BASED				
Figure	MSR	PSNR	Entropy	Brightness_Error
1	-3.6076e+0.06	17.4414	0.0012	-101.7138
2	-2.8235e+0.06	16.3770	0.0017	-105.0655
3	-1.2076e+0.06	12.6883	0.089	-68.3634

Table 1

CONCLUSION

Luma Based Multi Scale Retinex with color restoration method proposed in this paper has been achieved by testing across various images. Future work would concentrate on achieving this automated value through mathematical analysis.

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