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Color Image Enhancement Using Retinex Algorithm

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ABSTRACT: *Images we seen through a camera and direct observation of it is slightly different due to the calibration and less dynamic range of camera. In this paper we are proposing a method called Retinex method which models the human vision system. Through this we can interpret the actual image without any discrepancy between the two. So here the enhancement is done through Retinex Algorithm*

Keywords: *Colour image enhancement, colour constancy, dynamic range compression, Multi Scale Retinex, Histogram Equalization*

I. INTRODUCTION

There exists a common discrepancy between the direct observation of scenes and images captured through cameras.. For example, human can see details both in deep shadows and in nearby highly illuminated areas. On the other hand, a photograph of the same scene will either show the shadow as too dark, or the bright area as overexposed. The idea is to process the captured image, possibly in conjunction with the capture itself, so that the reproduction does not have these problems. One of the main reason for this is due to the low dynamic range compression of camera. Dynamic range is a ratio of highest value to the lowest value of a physical quantity. In the case of an image it is the ratio of highest pixel value to the lowest pixel value. For human vision system this range is very high that it can capture very high illuminant image and is approximately 10,000:1 in a single view. But this is not the case for an image capturing system which is very less compared to this. So one of our strategy is to reduce the dynamic range of the original image while capturing.

Colour constancy is the invariance of image colour with respect to the illumination present. Colour is not same for an image in different illumination. If colour appearance is a useful feature in identifying an object, then colour appearance must be constant when the object is viewed in different context.

Methods proposed earlier either work for dynamic range compression or colour constancy, both can be achieved using Retinex method. This was first proposed by Land [8]-[9] in 1986 this method has an advantage over an information content perspective which means that the scene replication can be made. As said a reasonable degree of colour constancy is present after MSR processing. Another advantage lies in both the local and global dynamic range compression of images. There is a wide variety of applications for this method ranging from aviation safety to general purpose photography.

In this paper along with the global enhancement, using filtering, the edges are also smoothed to get an impressive look of the image from camera.

II. OVERVIEW OF ENHANCEMENT METHODS

2.1. Previous methods

Histogram Equalization (HE) [12], is a technique that make contrast adjustment using image’s histogram. 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. The basic operation is remapping the histogram of the scene to a histogram that has a near uniform distribution thereby reassigning dark regions into brighter regions and brighter regions into darker regions. This technique improves contrast and the goal of Histogram Equalization is thus to obtain a uniform histogram. Homomorphic Filtering [13] is used to remove multiplicative noise. Illumination and reflectance are not separable, but their approximate locations in the frequency domain may be located. Since illumination and reflectance are combined multiplicatively, the component are made additive by taking the logarithm of the image intensity, so that these linearly in the frequency domain. Illumination variations can be thought of as a multiplicative noise, and can be reduced by filtering in the log domain. But this method results in the bleaching of the image. The simplest approaches for the enhancement of the under-/over-exposed regions of SDR images are global methods, [14], which apply the same compression curve to all image pixels. Such methods are the gamma correction and the logarithmic or any other power-based encoding.

The main advantage of these approaches is their simplicity, which results in fast execution but usually the improvement of one region is accompanied by the deterioration of another. Better results can be obtained by local methods. Contrast Limited Adaptive Histogram Equalization , [16] is another method for enhancing blurred images especially under water images, originally developed for medical imaging and has proven to be successful for enhancement of low contrast images such as portal films. . But it is to be noted that noise amplification in flat region and ring artifacts at strong edges also results from this method.

The most important of all the local methods is the Retinex family of algorithms which can overcome the above mentioned methods.

2.2. Retinex Methods

The idea of the retinex was first proposed by Land [8]-[9] in 1986 as a model of human vision which includes the lightness and colour perception of human eye. Through the years, Land gives the concept from a random walk computation [8] to its last form as a center or surround spatially opponent operation [9], which is similar to the neurophysiologic functions of individual neurons in the primate retina, lateral geniculate nucleus, and cerebral cortex.

Following Land, Hurlbert [10]-[11] studied the properties of this form of retinex and other lightness theories and found that they share a common mathematical basis. Certain scenes violate the "gray-world" assumption, which is the requirement that the average reflectance in the surround be equal in the three spectral colour bands. For example, in the case of monochrome scenes. it clearly violates this assumption and are forced to be gray by the retinex computation. Hurlbert further studied the lightness problem as a learning problem for artificial neural networks and found that the solution had a center/surround spatial form. Finally Hurlbert proposed a Gaussian surround function through his research as the surround function. The main concept Single Scale Retinex and Multi Scale Retinex was proposed by Jobson et al. [2]-[6]

III. METHODOLOGY

Retinex method merely bridges the gap between direct view and the image captured. The basic Retinex is the Single Scale Retinex proposed by Jobson et al. but it can either provide tonal rendition or dynamic range compression. Later they proposed the Multi Scale Retinex which will render both. A colour restoration step is also needed following MSR to overcome gray world violations for certain images. It merges all the necessary ingredients to approximate the performance of human vision with a computation that is quite automatic and reasonably simple. So this is an efficient method for enhancing any image that suffer from lighting deficiencies commonly encountered in architectural interiors and exteriors, landscapes, and nonstudio portraiture.

2.3. Single Scale Retinex

The single-scale Retinex (SSR) for a single spectral band can be represented as:

$$R_i(x,y) = \log I_i(x,y) - \log[F(x,y) * Ii(x,y)] \qquad (1)$$

where $Ii(x, y)$ is the image distribution in the ith colour spectral band, x and y are image coordinates, * denotes the convolution operation, $F(x, y)$ is the surround function and $Ri(x, y)$ is the respected Retinex output.

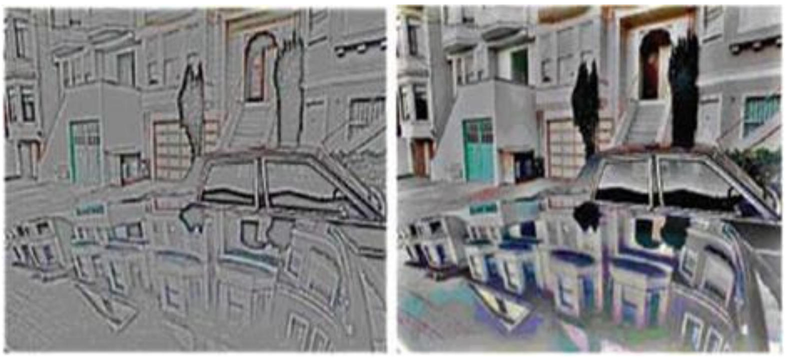
$$F(x, y) = K \exp(-r^2/C^2)$$

C is a scalar value called surround space constant or Gaussian space constant and K is selected such that

$$r = (x^2+y^2)^{1/2} \qquad \iint F(x, y)\, dx\, dy = 1$$

Small kernels results in good dynamic range compression. With large kernels the output looks more like the original scene. Middle value of surround space constant is good for compensating shadow and to achieve acceptable tonal rendition for the processed image.

Original image Gaussian space constant 250



Gaussian space constant 15 Gaussian space constant 80

Fig 1: Test image processed with different Gaussian surround space constants. Small value of space constant highlights fine details; Middle compensates shadow; higher values give better colour rendition

2.4. Multi Scale Retinex

When the dynamic range of scene exceeds the dynamic range of the recording medium, there is a loss of information which cannot be recovered. Single-scale Retinex (SSR) can either provide dynamic range compression or tonal rendition but not both simultaneously. To combine the strength of various surround space Multi-scale Retinex (MSR) was developed.

Multi-scale Retinex output is the weighted sum of the different SSR outputs. Mathematically:

$$R_{MSR} = \sum W_n \, R_{ni} \qquad i=1 \text{ to } n \tag{2}$$

where n is the number of scales, Rni is the ith component of the nth scale, RMSR is the ith spectral component of the MSR output, and Wn is the weight associated with the nth scale. In MSR the surround function is given by

$$F_n\,(x, y) = K \exp(\,-r^2 / C_n^{\,2}\,)$$

where Cn is the Gaussian surround space constant. Multi Scale Retinex combines the dynamic range compression of the Single-Scale Retinex with the tonal rendition to produce an output which encompasses both as shown in the figure below.

Fig 2: MSR output for test image. MSR combines the strength of each scale

Although MSR gives better results by combining dynamic range compression and colour rendition, it suffers from 'graying-out' of uniform parts. This requires colour restoration after MSR. This can be solved by the method Multi Scale Retinex with Colour Restoration (MSRCR).

2.5. Multi Scale Retinex With Colour Restoration

Images which violate gray-world assumptions on retinex processing suffer from 'graying-out' of the image, either globally or in specific regions. Thus gives a washed out appearance for the processed images. To restore colour MSR was modified by adding a colour restoration function given as:

$$R_{MSRCR} = C_i\,(x,y)\; R_{MSRi}\;(x,y) \tag{3}$$

where ,

$$C_i(x,y) = f\,[I_i^{'}(x,y)]$$

and

$$I_i^{'}(x,y) = I_i(x,y) \,/\, \textstyle\sum I_i(x,y)\;\textbf{,}\;\; \text{with i ranging from 1 to S}$$

where $I_i^{'}(x,y)$ is the ith band of the colour restoration function (CRF), RMSRCR is the ith spectral band of the Multi-scale Retinex with colour restoration(MSRCR), **S** is the number of spectral channels. The value of **S** is generally 3 for RGB.

Results show that the function that provides the best overall colour restoration is given by,

$$C_i(x,y) = {}_{\beta} \log\,[\,\alpha\, I_i^{'}(x,y)]$$

where α controls the strength of the non-linearity and β is a gain constant. The final gain/offset adjustments are required for transition from the logarithmic to the display domain. The final version of the MSRCR can be written as:

$$R_{MSRCR} = G[C_i(x,y)\{\,\log I_i(x,y)\text{-}\log[F(x,y)*Ii(x,y)]\}+b] \tag{4}$$

where G and b are the final gain and offset values

Fig 3: Multi-scale Retinex with colour restoration for better colour rendition.

As with this MSRCR there is still present certain artifacts, which results in the darkening at the high contrast areas. This must be reduced. This can be done either through filtering or through changing the surround function.

2.6. Method For Reducing Artifacts Using Histogram Equalization

The edge's high contrast gives no good visual impression. This can be overcome by either using average filtering or histogram equalization. Here we are adopting histogram equalization for enhancing the high contrast edges. So the image after colour restoration is subjected to histogram equalization to get the edges smoothened and ends in a good visual representation of image as shown in the figure below.

Fig 4: Result image of the proposed method using histogram equalization.

IV. CONCLUSION

Even though SSR provides good enhancement to images, it is not good for rendering both large scale and small scale enhancement simultaneously. It depends on the space constants using. This can be overcome through MSR which combines different space constants which renders high dynamic range compression, good tonal rendition and colour consistency even for the images violating gray world assumption. But the colour consistency is seem to be less at some regions especially at the dark regions, which have high contrast which can be limited by restoring the colour. This can be successfully made through colour restoration step in which a colour restoration function is used which is related to the chromaticity of image. Finally even if the restoration is made there is still some artifacts at the edges which seems to be like high contrast at the edges. This can be limited by either using histogram equalization or average filtering. Here we adopted the histogram equalization for reducing artifacts.

V. FUTURE WORKS

Proposed method gives good enhancement to the images but still there is desaturation of colour. Future work is to find the optimal range of surround space constant as well as number of scales required for proper colour rendition. Implementing this in hardware is also in consideration. In the long run if a better algorithm is obtained for reducing artifacts, this can be subjected to adaptation

(a) (b)

(c) (d)

Fig 5: (a) Original image (b) Result of MSR (c) MSRCR output image
(d) Image obtained using proposed method

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