# Improved Retinex approach for color image enhancement

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## Abstract

*An image enhancement model based on the Human Visual System is proposed. Image enhancement processing normally decreases image quality in some aspects, because the representation of color space is not linear.*

*The Retinex algorithm can be generally used in mamy kinds of images by considering human visual perception. The existing Retinex algorithm both Single-Scale Retinex and Multiple-Scale Retinex, do not take into account the local variations of the contrast within an image scence. Therefore the performance advantage of these models is limited.*

*A modified Retinex algorithm by using non-isotropic Gaussian kernel filters to fit the human visual system and the image perception quality is increased by equalizing the obtained Retinex ratio in logarithm. The processing is accomplished by cope the various scales of the window support regions yielding a multiscale enhanced images.*

*A number of experiments are conducted to demonstrate the performance of the proposed algorithm.*

## Introduction

Color image enhancement can be achieved by many approaches. Retinex theory is one of the most effective and robust amongst the existing methods. Retinex theory suggests that perceived color depends on reflected spectrum, but also on surroundings. Relative reflectance is more important than absolute reflectance. Goal of Retinex is to estimate the lightness of a surface in each channel by comparing the quantum catch at each pixel or photoreceptor to the value of some statistic.

A number of approaches have been proposed to improve existing Retinex methods from single scale to multiple scales of the neighborhood being used. The main exploit factor based on the small scale of neighbor yields a good dynamic compression but at the cost of loss tone rendition quality, vice versa for that in using larger scale. The proposed method enhance the Retinex approach by using non-isotropic Gaussian kernel filters to fit the human visual system associated with the manipulation weighted neighbor in multiple scales of Retinex and re-mapping intensity value to the display values with logarithmic intensity value to compress the high dynamic range images.

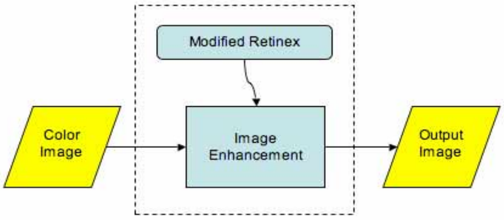


*Figure 1 Flow chart of the improved Retinex theory*

## Proposed Modified Retinex

The proposed method is to overcome the limitation of the unpleasant of the satuarated chromatic component existing in current Retinex approach to accomplish the color image enhancement. The flow char of the method is illustrated as Figure 1. There are five main phases in the proposed work. Mainly, these are accomplished in the logarithmic intensity based on the Retenix theory over different scales of affecting neighbor. Enhancement is applied by modifying luminance histogram to preserve the local contrast visibility. The equalized histogram is combined with Retinex ratio. The combination is derived and shown to be consistent with the original Retinex theory. The flow chart is detailed as follows.

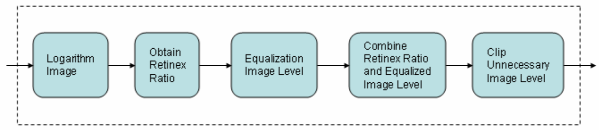


*Figure 2 Detail of the improved Retinex theory*

### *1.Computing Logarithm image and Retinex ratio*

For an original Retinex theory applying to an image I with an scale adaptive window F, the ratio of the each percieved component R can be obtained as (1.1)

$$R_i(x,y,c) = \log\{I_i(x,y)\} - \log\{F(x,y,c) * I_i(x,y)\} \qquad (1.1)$$

where $F(x,y,c)$ is a low-pass filter to simulate human perception, with c as the adaptive width of the Gaussian curve as (1.2).

$$F(x,y,c) = e^{-\left(\frac{(x-\mu)^2+(y-\mu)^2}{c^2}\right)} \qquad (1.2)$$

The proposed approach is to modify the result of existing Retinex theory [2,3,4,11,12,14], where the Retinex ratio is employed into the approach to compress the high dynamic range images to achieve lower the over bright region and raise the darker area in the scene locally. For different emphasized region perceived by human, in [4] proposed a weighted MSR as,

$$R_{M_i}(x,y,w,c) = \sum_{n=1}^{N} w_n R_i(x,y,c_n) \qquad (1.3)$$

where $w_n$ is the nth SSR weighting value and $c_n$ is the scale of each nth SSR with $\sum_{n=1}^{N} w_n = 1$.

In [14], the difference of the connected regions is further enhanced with modified weighting values to obtain the human perception Ratinex ratio with detail visibility being preserved that is incorporated in the proposed method. The weighting factors $w_1$, $w_2$ and $w_3$ are obtained as follows,

$$f_i(x,y)=\sqrt{\frac{1}{MN}\sum_{p=1}^{M}\sum_{q=1}^{N}\left[I_i(p+1,q)-I_i(p,q)\right]^2} \tag{1.4}$$

$$f_{i,u}(x,y)=\left(f_i(x,y)-f_{i\min}(x,y)\right)/\left(f_{i\max}(x,y)-f_{i\min}(x,y)\right) \tag{1.5}$$

$$\begin{aligned} w_1 &= w_2 = f_{i,u}/2, \\ w_3 &= 1-f_{i,u} \end{aligned} \tag{1.6}$$

To fit the HVS, the weight factor of the neighbor region can be further classified into three regions by shape the window as shown in the Figure 3.

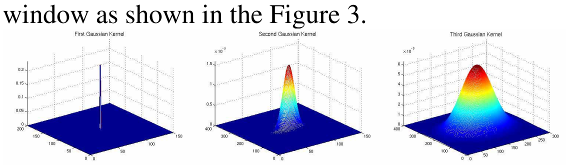


*Figure 3 Three types of anisotropical low pass filters $R_1$, $R_2$ and $R_3$.*

These filters can be implemented as follows in equation (1.7),

$$\begin{aligned} R_{1_i}(x,y,c_1) &= \log_{10}(I_i(x,y))-\log_{10}\left(F_1\left(x/4,y/4,c_1\right)*I_i(x,y,c_1)\right) \\ R_{2_i}(x,y,c_2) &= \log_{10}(I_i(x,y))-\log_{10}\left(F_2\left(x/2,y/4,c_2\right)*I_i(x,y,c_2)\right) \\ R_{3_i}(x,y,c_3) &= \log_{10}(I_i(x,y))-\log_{10}\left(F_3\left(x/2,y/2,c_3\right)*I_i(x,y,c_3)\right) \end{aligned} \tag{1.7}$$

The proposed research is than carried out color restoration as that in [14] and shown in (1.8).

$$R_{M_i}(x,y,w,c,C)=R_{M_i}(x,y,w,c)*I_i(x,y,c) \tag{1.8}$$

where $I_i(x,y,C)$ is given in (1.9) as

$$I_i(x,y,C)=\log_{10}\left(1+CI_i(x,y)/\sum_{i=1}^{3}I_i(x,y)\right) \tag{1.9}$$

c and C are the window scale and the color components, R, G, and B respectively. The reason to apply the color information from the input image is to restore the color according to the proportion of color component existing in the testing image.

## *2. Equalization of light source*

An image 'I' of an object is formed from luminance source 'S' times reflectivity of the object 'r' as,

$$I_i(x,y)=S_i(x,y)\times r_i(x,y) \tag{2.1}$$

For a uniform light source, the Retinex in (1.1) can be also obtained equivalently in (2.2) as

$$\begin{aligned} R_i(x,y,c) &= \log_{10}(I_i(x,y))-\log_{10}(F(x,y,c)*I_i(x,y)) \\ \Rightarrow R_i(x,y,c) &= \log_{10} I_i(x,y)/(F(x,y,c)*I_i(x,y)) \\ \Rightarrow R_i(x,y,c) &= \log_{10}(S(x,y)\times r(x,y))/(\bar{S}(x,y)\times\bar{r}(x,y)) \end{aligned} \tag{2.2}$$

where $\bar{S}$ is average of light source and $\bar{r}$ is average of object reflectivity. By replacing $F(x,y,c)*I_i(x,y)$ with $\bar{S}(x,y)\times\bar{r}(x,y)$ corresponds to the luminance mean value which is equivalently to the result of a convolution. Thus, (2.2) can be further written as (2.3)

$$R(x,y,c)\approx\log_{10}\frac{r(x,y)}{\bar{r}(x,y)} \tag{2.3}$$

In (2.3) illustrates that image formation difference is linear proportional to that of the object reflectivity. For the non-uniform light source produces unpleasant low contrast of the image, the robust image equalization is applied to the light source 'S' to enhance the contrast as in (2.4).

$$S_{eq}=equalize(S) \tag{2.4}$$

## *3. Combine Retinex and equalized light source*

The enhanced image $I'$ can be directly obtained by multiplying the equalized light source and exponential Retinex ratio as

$$I' = S_{eq}\times R_{\exp} \tag{3.1}$$

where

$$R_{\exp}(x,y)=\exp(R(x,y)) \tag{3.2}$$

## Experiments to illustrate the efficacy of the proposed method

In order to evaluate the performance of the proposed method, the input image is converted to the SRGB format for further color difference calculation. The testing image is in Figure 4.1.

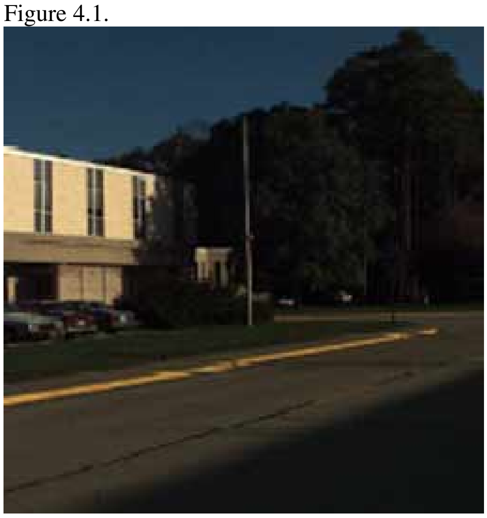

*Figure 4.1 testing image*

In Figure 4.2 is an outcome of taking testing image as input and performed the original Retinex theory with single scale neighboring region approach. The color rendition has been improved significantly. The detail of the leaves on the tree has been blurred.

*Figure 4.2 Output of testing image after SSR*

In Figure 4.3 shows the result of Multi-scale Retinex approach. The edge feature of the leaves on the tree has been sharpened while keeping the contrast rendition.

*Figure 4.3 Output image of MSR method*

*Figure 4.4 Output of combined equalized image and weighted MSR after SSR*

*Figure 4.5 Output of the testing image with proposed MSR method*

In Figure 4.4 shows the result of the equalization of the logarithmic luminance value with Multi-scale Retinex approach. The edge feature of the leaves on the tree has been sharpened while keeping the contrast rendition.

In Figure 4.5 shows the output of the proposed MSR method. The rending quality has improved.

In Figure 4.6 to Figure 4.9 show some different features of testing images and the results. In Figure 4.6 is a color casting image and Figure 4.7 the result after applied the proposed method. Figure 4.8 is a high dynamic range image, the result after employed the proposed method is shown in Figure 4.9.

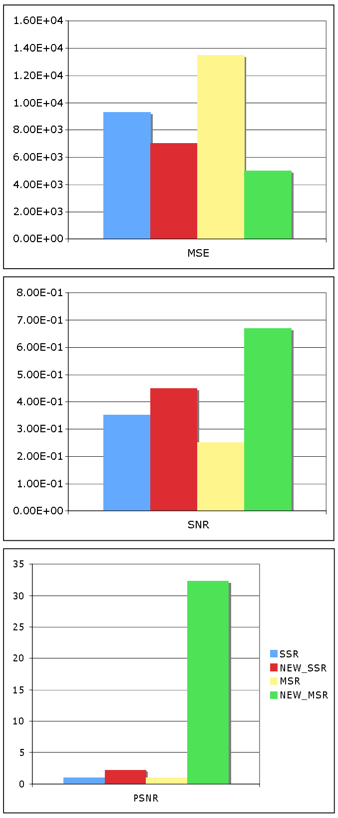


*Figure 4.6 Evaluation of the enhancement via MSE, SNR and PSNR.*

There are three assessment of the enhancement MSE, SNR and PSNR. Similar to the computational quantity of the general algorithm evaluation, the absolute MSE assessment is a reference. The remaining assessment results show that SNR and PSNR of the proposed modified Retinex theory has best performance. The experiment results show that the traditional Retinex exhibits the color saturation yielding unpleasant view but with good dynamic range compression. The proposed method has been tested over various images show that the local contrast can be effectively increased and provides good rendition color.

## Conclusions

Single scale Retinex is hard to keep balance on dynamic compression and tone rendition depending on scale being chosen. Multiple scales of Retinex could achieve both good dynamic range compression and color rendition for general images. The proposed method shows improvements on color images both in color restoration and better contrast. Some more sophisticated analysis algorithms in image enhancement can also be applied before combining the modified illuminant histogram and weighted Retinex ratio. The modification of the illuminant distribution can be incorporated such as the sigmoidal function tone mapping to further ensure the result would remain in pleasant contrast range by locally handled statistically and this is currently being investigated.

## Acknowledgement

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## Author Biography

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*Figure 4.6 Color casting image for testing.*


*Figure 4.7 The result of proposed method*


*Figure 4.8 A high dynamic range image for testing.*


*Figure 4.9 The result of the proposed method.*