CONTRAST ENHANCEMENT OF COLOR IMAGES USING IMPROVED RETINEX METHOD

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Abstract

Color images provide large information for human visual perception compared to grayscale images. Color image enhancement methods enhance the visual data to increase the clarity of the color image. It increases human perception of information. Different color image contrast enhancement methods are used to increase the contrast of the color images. The Retinex algorithms enhance the color images similar to the scene perceived by the human eye. Multiscale retinex with color restoration (MSRCR) is a type of retinex algorithm. The MSRCR algorithm results in graying out and halo artifacts at the edges of the images. So here the focus is on improving the MSRCR algorithm by combining it with contrast limited adaptive histogram equalization (CLAHE) using image.

Keywords: *color image enhancement,retinex algorithms*

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1. INTRODUCTION

Contrast enhancement in color images increases the contrast of a color image to improve its quality. In images, it increases human perception of information. In image processing techniques, it gives good input. The unwanted information gets added into the captured image due the restricted capacities of the device used for capturing images and the atmospheric changes. This results in blurring of images. So the captured image suffers from information losses which reduce its quality. Thus image enhancement techniques play an important role in recovering the useful information from the image. The image enhancement techniques are used in aerospace, safety and security, consumer, medical, forensic applications.

When the illumination conditions are poor in the scene, then the image representation in the human observers eye and captured image's digital representation never matches with each other. The output image appears darker due to low contrast. So in order to match the recorded image with the observed image, the acquired images must undergo image enhancement to correctly represent the observed scene. Thus the image enhancement is a very important image processing preprocessing stage. After image enhancement, all the details of an image even under extremely dark background can be obtained. The different color image enhancement methods are histogram equalization, homomorphic filtering, contrast stretching, retinex algorithms and adaptive histogram equalization.

Human eyes can detect the colors in a correct way even when the lighting conditions are poor. But cameras cannot do it. Retinex algorithms are based on human eyes biological mechanisms of adjusting to the conditions of lighting. The word Retinex is derived from the words retina, which is part of the human eye, and cortex, which is part of the human brain that plays important role in human vision. The Retinex algorithms are contrast enhancement methods which improves the visual appearance of images. It is an image enhancement method that provides color rendition, dynamic range compression and color constancy.

The color constancy is an important feature of the human color perception system. It is the property by which the color perceived by human remains almost constant when the illumination condition changes. At afternoon an orange appears orange in color in humans, when the main illumination is white and also at sunset, when the main illumination is red. This shows the color constancy of human vision. The Retinex algorithms give this color constancy along with dynamic range compression and color rendition.

The Retinex algorithm enhances the image similar to the human perception of the scene compared to any other color image enhancement methods. Thus retinex algorithms are very important color image enhancement method.

2. MOTIVATION

This work takes care of improving performance of retinex algorithm by combining it with contrast limited adaptive histogram equalization using image fusion. The quality parameters used are MSE(Mean Square Error),RMSE(Root Mean Square Error), PSNR(Peak Signal to Noise Ratio) and Structural Similarity Index(SSIM).

3. RELATED WORK

3.1 Color Image Enhancement Methods

When the illumination conditions are poor in the scene, then the image representation in the human observers eye and captured images digital representation never matches with each other [6].The images appear darker due to low contrast. The low contrast images are needed to be enhanced. Different methods are used to increase the contrast of the images. These contrast enhancement techniques increase the contrast of images and increases its quality.

Two methods for contrast enhancement are global and adaptive methods [3].A transformation is made on all pixels of the image in global method of contrast enhancement. Histogram equalization and linear contrast stretching are examples of global method. An input, output transformation is applied to the image in the adaptive method of contrast enhancement. It changes adaptively with the properties of the image.

Adaptive histogram equalization is the example of an adaptive method of contrast enhancement. The dynamic range of an image is stretched using the contrast stretching technique [7] to improve the contrast. The dynamic range is the range between the minimum intensity value and the maximum intensity value. It is mainly used to increase contrast of medical images.

Histogram Equalization (HE) [8] is another method of contrast enhancement. It uses the histogram of the image to adjust its contrast. It analyzes the number of pixels and they are spread evenly over the available frequencies to give an equalized image. If Histogram Equalization (HE) is applied directly on color image, it changes the properties of color channel which changes the color balance of the image. So HE should be applied to luminance or value by converting the image into LAB color space or HSV color space. So the hue and saturation of the image does not change.

Adaptive Histogram Equalization (AHE) is a type of Histogram Equalization, which uses an adaptive contrast enhancement technique. It computes many histograms, related to a distinct part of the image. The lightness values are redistributed using them. The local contrast of the image is increased by this method.

Homomorphic filtering [8] increases the contrast of an image by normalizing its contrast. It removes the multiplicative noise. Illumination variations are considered as multiplicative noise. Homomorphic filter is a high pass filter which passes the reflectance which is in the high frequency part and removes illumination variations which is in low frequency part. Thus the illumination variations which are a type of multiplicative noise can be reduced by using homomorphic filtering.

The two problems of image captured by camera due to limitations of lighting conditions of the scene are dynamic range problem and color constancy problem. The dynamic range problem is the loss of color and details in the shadowed areas of the image. When the illuminant has variations in the spectral distributions which is caused due to difference in daylight and artificial light by the camera, the distortions of color occurs in the image. It is the problem of color constancy.

The problem called color rendition occur in color images, when the processed image is matched with the observed image. It occurs as a result of halo artifacts and gray world assumption violations. These problems can be reduced using Retinex algorithms. Retinex algorithms [1] improve the color rendition, dynamic range compression, and color constancy of the digital image.

The retinex algorithms [4] are very sensitive to the color variations of nearby objects. It is based on the model of human color constancy. The retinex algorithm describes basic phenomena of color vision. The retinex algorithm [5] is used for providing photographs of wide dynamic range. It compresses large ratios and increases dynamic range and gives contrast enhancement. Retinex method can be used in poor visibility conditions using a bilateral filtering [6]. It uses a denoising method along with Retinex algorithm.

Single Scale Retinex algorithm [9] is the basic retinex algorithm which uses a single scale. It can either provide dynamic range compression or tonal rendition. Multi-Scales Retinex [10] for color image enhancement overcomes the problems of SSR. Multiscale Retinex [11] algorithm bridges the gap between color images and the human observation in which the tests were limited to the conventional dynamic range images.

A new color correction method is given to the multiscale Retinex algorithm using input images local contrast to give color enhancement [11].The suitable parameters of Gaussian filters are selected. It reduces artifacts made by multi scale retinex algorithm. The Multi scale Retinex with color restoration [11] produces dynamic range compression, color rendition and color constancy. The MSRCR can be used in space operations and remote sensing operations [13] .MSRCR combines color constancy with local contrast enhancement to produce digital images similar to observed scene.

3.2 Challenges Faced by Color Image Enhancement Methods

The contrast stretching stretches the dynamic range of image. It provides good visual representation of the original scene, but some of the detail may be loss due to clipping, poor visibility in under exposure regions of the image. The color constancy cannot be achieved by this algorithm. The homomorphic filtering is a high pass filter that removes the multiplicative noise. But it results in bleaching of the image.AHE has a tendency to over amplify the noise in relatively homogeneous regions of the image. SSR is the basic technique of retinex algorithm. But the resulting images suffer from halos and graying out. SSR is incapable of simultaneously providing sufficient dynamic range compression and tonal rendition.MSR provides dynamic range compression. The problems of MSR are the selection of the Gaussian filter set and the proper filter weights are not specified. MSR fails to meet with Gray World Assumption. So color restoration method for multi scale retinex method is very important. This color restoration can be obtained by using MSRCR algorithm.

4. EXISTING SYSTEMS

4.1 Retinex Algorithms

The Retinex image enhancement algorithm [1] [12] [13] is an image enhancement method that enhances an image with dynamic range compression. It also provides color constancy. It gives a computational human vision model. It deals separates two parameters. At first the illumination information is estimated and then the reflectance is obtained from using division. It is based on the image formation model which is given [1] by

$$I(x, y) = L(x, y)\, r(x, y) \quad (1)$$

Where I is the input image, L is illumination and r is reflectance. The image is first converted into the logarithmic domain [1] in which multiplications and divisions are converted to additions and subtractions that makes the calculation simple. The sensitivity of human vision reaches a logarithmic curve. The flowchart of Retinex algorithm is shown in the Fig 1. Here S is the input image. The illumination is estimated.

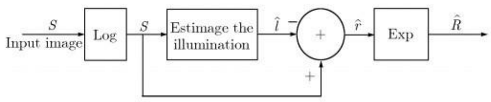


Fig.-1: General Flowchart of Retinex Algorithm [1]

Retinex is based on the center/surround algorithm [14].The given centre pixel value is compared with the surrounding average pixel values to get the new pixel value. The input value of the center surround functions is obtained by its centre input value and its neighborhood.

An array of photoreceptor responses is there for each image location. This is given as input to the retinex algorithm which has the receptor class for each location in the image. The algorithm calculates a series of paths. For a single receptor class, it estimates the lightness values as a spatial array.

For computing each path, a starting pixel (x1) is first selected [15].Then a neighboring pixel (x2) is randomly selected. The difference of the logarithms of the sensor responses at the two positions is then calculated.

The position of pixel x2 is obtained by adding the previous step with the accumulator register which is given by:

$$A(x2) = A(x2) + \log(x2) - \log(x1) \quad (2)$$

Where A(x2) is the accumulator registers for pixel (x2). Counter register N(x2) for position x2 is incremented. All registers and counters are set to zero when the calculation starts.

The accumulation of position (xi) on the path is calculated by [15]:

$$A(xi) = A(xi) + \log(x1) \quad (3)$$

Then the counter register N (xi) is incremented. The first element of the path thus plays an important role in the accumulation for the path calculation. The mathematical form of a Retinex is given by:

$$Ri(x, y) = \log Ii(x, y) - \log[F(x, y) * Ii(x, y)] \quad (4)$$

Where I is the input image, R is the Retinex output image and F is the Gaussian filter (surround or kernel) which is given by:

$$F(x, y) = K\exp[-(x^2+y^2)/\sigma^2] \quad (5)$$

Where K is a normalization factor

The Retinex enhancement algorithms can be applied on all pictures. It provides better dynamic range compression and color rendition. It is an automatic process independent of inputs. These are the advantages of retinex algorithms. [15]:

The different types of retinex algorithms are:
(i)Single Scale Retinex algorithm (SSR)
(ii) Multiscale Retinex algorithm (MSR)
(iii)Multiscale retinex with Color Restoration algorithm (MSRCR)

4.2 Single Scale Retinex Algorithm (SSR)

Single Scale Retinex [15], is the most basic method for Retinex algorithm. A low pass filter is applied on Ii (x, y) which is the input color image to estimate the illumination. This illuminations log signal is subtracted to get the output color image Ri(x,y).It is a 2D convolution of Gaussian surround function and ith component of the original image.

It is given by [16],

$$R_i(x, y) = \log I_i(x, y) - \log[F(x, y) * I_i(x, y)] \quad (6)$$

Where i=1...S. Here,

$$F(x, y) = K\exp[-(x^{2+}y^2)/c^2] \quad (7)$$

is Surround Function, S is the number of spectral bands, c is surround constant or scale value and selection of K is such that $\iint F(x,y)\, dx\, dy = 1$.

The log function in SSR [9],[2] is placed after the Gaussian surround function. A canonical gain offset is used as a post retinex signal processing. A space constant of 80 pixel is a good compromise between dynamic range compression and tonal rendition.

A single scale cannot simultaneously provide dynamic range compression and tonal rendition. The images are either locally or globally grayed out or suffered from color distortion due to violations of the gray world assumptions. These are the drawbacks of SSR.

4.3 Multi Scale Retinex Algorithm (MSR)

Single-scale Retinex cannot provide both the dynamic range compression and tonal rendition.Multi Scale Retinex (MSR) [9] is developed to combine the strength of different surround spaces. The Gaussian filters of different sizes are used to process input image several times. The resulting images are weighted and summed to get output of MSR [17].

It is given by [18]

$$R_i(x, y) = W_n \log I_i(x, y) - \log [F_n(x, y) * I_i(x, y)] \qquad (8)$$

Where i=1, .S.

Here, Wn represents the weight for the net scale, N is number of scales.

MSR [18][2] provide color enhancement. It also provides dynamic range compression and tonal rendition. The halos are reduced by using MSR.

But MSR output images violate gray world assumptions. So it suffers from greying out of the image, either globally or locally. This gives a washed out appearance. This is the main drawback of MSR algorithm.

4.4 Multi Scale Retinex with Color Restoration Algorithm (MSRCR)

To restore color, MSR is modified by adding a color restoration function [4]. The color restoration factor is given [18] by:

$$\alpha_i(x, y) = f[I_i(x, y) / \textstyle\sum_{n=1}^{N} I_n(x, y)] \qquad (9)$$

It is the color restoration coefficient in the ith spectral band. The number of spectral bands is given by K.MSRCR algorithm is given by,

$$R_i(x, y) = \alpha_i(x, y) \textstyle\sum_{k=1}^{K} W_k \log I_i(x, y) - \log [F_k(x, y) * I_i(x, y)] \qquad (10)$$

The block diagram of MSRCR algorithm is shown in fig.2 MSR algorithm fails to meet Grey World Assumption. This problem can be removed by using color restoration method. Thus a color restoration factor (CRF) block is added with the MSR block to obtain the MSRCR algorithm

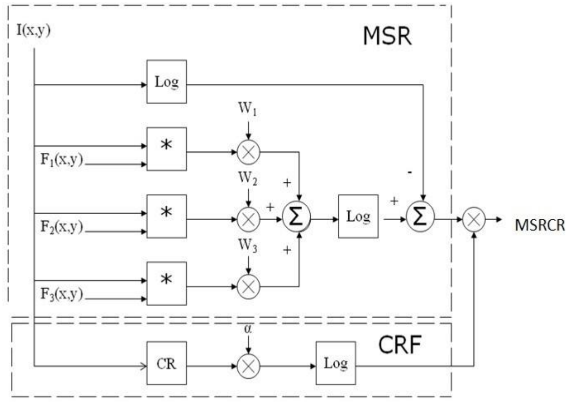


Fig-2: Block Diagram for MSRCR Algorithm [2]

Main problems of MSRCR algorithm are the presence of halo artifacts at edges, graying out [16] of low contrast areas and bad color rendition. The MSRCR has halo artifacts [19] in high contrast edges. The greying out effect of MSRCR is reduced by using adaptive filtering [16] on luminance channel. At high contrast edges, these adaptive filter adapt the shape of the filter. In this way they reduces the greying out and halo artifacts [16].But even then halo artifacts remains in images enhanced by using adaptive image enhancement methods [19]. Halo artifacts in color images using, a fast edge preserving filter [20].But it reduces the contrast. The Gaussian surround function is modified in [21] to reduce halo artifacts. But still it results in desaturation of color.

5. PROPOSED SYSTEM

The proposed system is a modification of multiscale scale retinex with color restoration algorithm [4].It reduces the halo artifacts [16] and graying out of images [19] of multiscale retinex with color restoration algorithm and increases clarity of images.

The improved MSRCR method uses multiscale retinex with color restoration algorithm and contrast limited adaptive histogram equalization. The Contrast limited adaptive histogram equalization and the multiscale retinex with color restoration methods are applied to the low contrast image separately. The image fusion is used to combine their outputs. The output image obtained has more clarity than the output of existing multiscale retinex with color restoration algorithm.

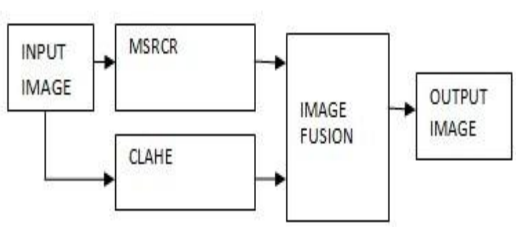


Fig-3: Block Diagram for improved MSRCR Algorithm

A low contrast image is given as input image. The MSRCR algorithm is applied on this low contrast image. But the output image has graying out and halo artifacts at the edges. CLAHE is Contrast Limited Adaptive Histogram Equalization. It operates on small regions of the image [22].These small regions are called tiles. The bilinear interpolation is used to combine these small regions of the image. By limiting the contrast in homogeneous areas, it reduced the noise in the images. It enhances the contrast of these small regions of the image. The edge based color constancy can be attained by using CLAHE. It improves the local contrast of images. So graying out of the images and halo artifacts at the edges can be reduced using CLAHE. . CLAHE cannot be applied directly to the color channels in a color image as it changes the color balance of the image. So the image is first converted to the LAB color space. Then the algorithm is applied. After that the output image is converted back to the RGB color space. The image fusion is used to combine the information in the two images into a single image which has more information than any of the two input images. Here image fusion block combines the output image of MSRCR and output image of CLAHE to produce single enhanced output image. It merges the two images by wavelet decompositions [23].So the output image compare to the old MSRCR output image thus improving the clarity of the MSRCR output image.

6. RESULTS AND DISCUSSIONS

The software simulation tool used is MATLAB R2012a. Three low contrast test images are used as input images. Since these images have low contrast, they appear darker. The SSR, MSR, MSRCR, Improved MSRCR algorithms are applied on this three images. These algorithms enhance the contrast of the input image. The simulation results clearly show that the Improved MSRCR output images have more clarity than the SSR, MSR and MSRCRoutput image. The quality parameters used for comparison are Mean Square Error (MSE), Root Mean Square Error (RMSE), PeakSignaltoNoise Ratio (PSNR), and Structural Similarity Index (SSIM).

(a) (b)

(c) (d)

(e)

Fig.-4: a)Test Image1 b)SSR Output Image c)MSR Output Image d) MSRCR Output Image e)Improved MSRCR method

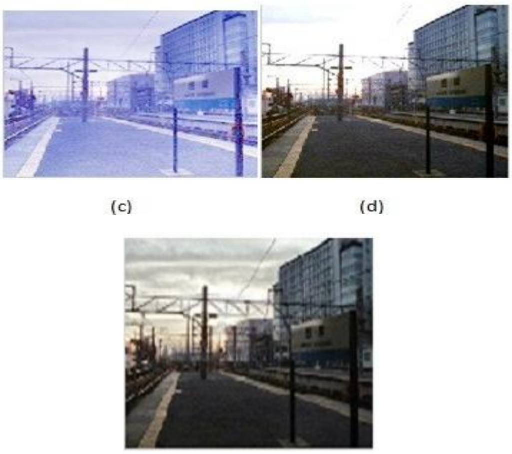
(a) (b)

(c) (d)

(e)

Fig.-5: a)Test Image2 b)SSR Output Image c)MSR Output Image d) MSRCR Output Image e)Improved MSRCR method

(a) (b)



(e)

Fig.-6: a)Test Image2 b)SSR Output Image c)MSR Output Image d) MSRCR Output Image e)Improved MSRCR method

Table 1 MSE Calculation

Image	SSR	MSR	MSRCR	Improved MSRCR
Test Image1	0.2430	0.2319	0.0802	0.0387
Test Image2	0.2801	0.2560	0.0805	0.0341
Test Image3	0.2893	0.2603	0.0478	0.0211

Table 2 RMSE Calculation

Images	SSR	MSR	MSRCR	Improved MSRCR
Test Image1	0.4929	0.4816	0.2833	0.1967
Test Image2	0.5293	0.5060	0.2837	0.1845
Test Image3	0.5378	0.5102	0.2186	0.1451

Table 3: PSNR Calculation

Images	SSR	MSR	MSRCR	Improved MSRCR
Test Image1	54.2756	54.4774	59.0871	62.2551
Test Image2	53.6573	54.0480	59.0741	62.8091
Test Image3	53.5181	53.9762	61.3370	64.8957

Table 4: SSIM Calculation

Image	SSR	MSR	MSRCR	Improved MSRCR
Test Image1	0.9697	0.9718	0.9899	0.9955
Test Image2	0.9600	0.9634	0.9888	0.9964
Test Image3	0.9660	0.9708	0.9940	0.9976

7. CONCLUSION

A method to improve the performance of the MSRCR method is proposed in this paper. The proposed method combines the MSRCR algorithm and contrast limited adaptive histogram equalization using image fusion. . This improved retinex method provides PSNR, SSIM values greater than the existing color image enhancement methods. It also has the lowest MSE and RMSE values. The proposed method reduces the halo artifacts and graying out and thus improves the existing MSRCR method.

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