Color Correction Using Chromaticity of Highlight Region in Multi-Scaled Retinex

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ABSTRACT

In general, as a dynamic range of digital still camera is narrower than a real scene's, it is hard to represent the shadow region of scene. Thus, multi-scaled retinex algorithm is used to improve detail and local contrast of the shadow region in an image by dividing the image by its local average images through Gaussian filtering. However, if the chromatic distribution of the original image is not uniform and dominated by a certain chromaticity, the chromaticity of the local average image depends on the dominant chromaticity of original image, thereby the colors of the resulting image are shifted to a complement color to the dominant chromaticity. In this paper, a modified multi-scaled retinex method to reduce the influence of the dominant chromaticity is proposed. In multi-scaled retinex process, the local average images obtained by Gaussian filtering are divided by the average chromaticity values of the original image in order to reduce the influence of dominant chromaticity. Next, the chromaticity of illuminant is estimated in highlight region and the local average images are corrected by the estimated chromaticity of illuminant. In experiment, results show that the proposed method improved the local contrast and detail without color distortion.

Keywords: Retinex, illuminant estimation, Gaussian filtering

1. INTRODUCTION

Retinex theory, as a model of the lightness and color perception of human vision, introduced by Land is evolved into center/surround retinex model by the ratio of the lightness for a small central field of the region of interest to the average lightness over and extended field [1]. Single scale retinex using a Gaussian filter is proposed to improve the image appearance based on the center/surround retinex model. However, in the single retinex algorithm there are the several defects, such as halos and graying-out, generated in large areas with uniform chromatic distribution. Thus, the multi-scaled retinex algorithm proposed by Jobson [2,3]. Through the weighted summing resulting images of single retinex processes with various-scale Gaussian filters, the halo artifact is considerably reduced and the local contrast is improved. In addition, the color restoration process by adding the chromaticity of the original image to the resulting image of multi-scaled retinex algorithm is supplemented to reduce the graying-out of resulting image [4]. However, after the color restoration process, the saturation of the resulting image is unnatural compared to the original image, because the variation of the lightness is not considered. Moreover, if the chromatic distribution of the image is not uniform and dominated to certain chromaticity value, the average chromaticity of the resulting image is shifted toward complement chromaticity to the dominant chromaticity, thereby inducing the undesirable color distortion, because it is based on the gray world assumption.

In this paper, the modified multi-scaled retinex using the chromaticity of highlight region is proposed to improve the color rendition. To reduce the influence of the dominant chromaticity in the image, the local average images in multi-scaled retinex are divided by the average chromaticity values of the original image. Then, the local average images are multiplied by the chromaticity of the global illuminant which is estimated by the averaged chromaticity values within the highlighted region, because the chromaticity from the highlighted region is independent to the dominant chromaticity of the image [5]. The output image is obtained by a weighted sum of images which are obtained by dividing the original image by the local average image. In addition, to reduce the graying-out induced, the chroma value of the output image is compensated based on that of the original image in CIELAB space.

2. MULTI-SCALED RETINEX

In general, the perceived color by the human eye can be considered the product between the reflectance of object and the illuminant. Thus, the reflectance is calculated by estimating the illuminant from the perceived color. The illuminant should be regionally estimated, because the illuminant has usually a nonuniform distribution and different chromaticity locally. The single scale retinex is the color constancy model under nonuniform illuminant. The Gaussian filter is used to estimate the illuminant component, and the reflectance is calculated by the difference between the original image and its Gaussian filtered image in logarithmic space as follows:

$$R_i(x,y) = \log I_i(x,y) - \log\{F(x,y) * I_i(x,y)\} \tag{1}$$

where $I_i(x,y)$ is the original image in the i-th spectral band for each coordinate position (x,y), $F(x,y)$ is the Gaussian filter, and the symbol "*" denotes the convolution operation. The Gaussian filter is given by

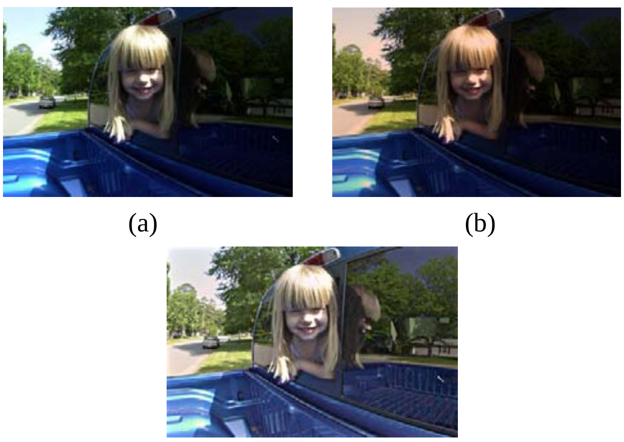
$$F(x,y) = Ke^{-(x^2+y^2)/\sigma^2} \quad \text{and} \quad \iint F(x,y)dxdy = 1, \tag{2}$$

where K is the normalized constant coefficient, and σ represents the standard deviation for the scale. Thus, the determine of parameter, σ, is very important, because the performance of single scale retinex is dependent on standard deviation, σ, in the Gaussian filter. Its small scale shows the result of a good dynamic range compression, contrastively the large scale shows the result of good color rendition. In addition, because the result for a scale is also depended on the input image, it is hard to determine the scale. Thus, to solve the trade-off between dynamic range compression and color rendition, the multi-scaled retinex is proposed. It is computed by the weighted sum of resulting images of single retinex processes with several scales as follows:

$$R_i(x,y) = \sum_{n=1}^{N} \omega_n \{\log I_i(x,y) - \log\{F_n(x,y) * I_i(x,y)\}\},$$

$$F_n(x,y) = Ke^{-(x^2+y^2)/\sigma_n^2}, \text{ and } \iint F_n(x,y)dxdy = 1, \tag{3}$$

where ω_n represents the weight for n-th scale. The result of single retinex using the small scale Gaussian filter has only the detail with graying out. In contrast, the result of single retinex using the large scale Gaussian filter has more information for the chromaticity. Thus, the local contrast and color rendition could be simultaneously obtained by weighted summation of those results. However, if the original image has high distribution for some chromaticity value, i.e. the average chromaticity of scene excluding the chromaticity of illuminant is not a gray, the chromaticity of the result is distorted toward the complement chromaticity, because the multi-scaled retinex is based on a gray world assumption. Fig. 1 shows the color distortion in multi-scaled retinex process.



(a) (b) (c)

Fig. 1: Comparison between (a) original image, (b) result image by gray world assumption, and (c) resulting image by multi-scaled retinex.

The average chromaticity of the image, Fig. 1(a), is dominated by a blue color of the car. Thus, in multi-scale retinex process, the chromaticity of locally averaged image is dominated by the blue, and the complement chromaticity, the chromaticity of magenta is added by the difference between the image and the locally averaged image. Accordingly, as shown in Fig. 1(c), the chromaticity resulting image is distorted, especially in the region of the sky and lawn, like a result of the gray world assumption, Fig. 1(b).

3. MODIFIED MULTI-SCALED RETINEX

3.1 Estimation of chromaticity for uniform illuminant

In general, the gray world assumption, one of the best-known algorithms for color constancy, is based on the assumption that the average of reflectances in the image are gray and can be considered to be a random variable drawn from the range [0,1]. The chromaticity values of the image are divided by its average chromaticity values to remove the illuminant component. Thus, it works well in the image with a sufficiently large number of different colors, i.e. reflectances are uniform distributed. However, if the chromatic distribution of the image is dominated by a certain chromaticity, the resulting image based on the gray world assumption becomes a grayish although the chromatic distribution of the image is not closed to the gray color. Accordingly, instead of averaging the chromaticity values to estimate the illuminant component, the chromaticity of illuminant is simply estimated by the averaged chromaticity value within the highlight region based on the assumption that the image has specular reflections in the highlight region. In addition, the highlight region is extracted in Gaussian filtered image to reduce the noise. The histogram of the Gaussian filtered image is used to extract the highlighted region in the image. The histogram for the each channel is represented as follows:

$$H_i(k) = histo\{F(x,y) * I_i(x,y)\}. \tag{4}$$

The highlight region in histogram is extracted by b such that

$$N \times p \le \sum_{k=1}^{b} H_i(k), \tag{5}$$

where N is the total number of image pixels, p is the ratio for highlight region in the image, and k indicates the index of bucket in histogram. Base on the b-th bucket, the highlight region is separated. The chromaticity of illuminant is then estimated by the average chromaticity value in the highlight region for each channel, as follows:

$$c_i = \frac{1}{N_h} \sum_{k=b}^{k_{max}} H_i(k) \times I_k, \tag{6}$$

where N_h is the number of total pixels in highlight region and I_k indicates the intensity for k bucket. The average values of intensity for each channel represent the chromaticity of the illuminant.

3.2 Correction for locally averaged images

The locally averaged images by Gaussian filtered image are regarded as the local illuminant component in multi-scaled retinex algorithm because it is based on the gray world assumption. Thus the local illuminant is estimated by low pass filtering with various-scale Gaussian filters, as shown in Fig. 2. However, if the image has a dominant chromatic distribution to a certain chromaticity, the chromatic distribution of the difference images between the image and its locally averaged images obtained by various-scale Gaussian filtering is moved toward the complement chromaticity to the dominant chromaticity, thereby provoking the undesirable color distortion. Accordingly, to correct the undesirable color distortion, the chromatic distribution of locally averaged images should be closed to the chromaticity value of the illuminant in the scene. Thus, first, the average chromaticity for the images is computed as follows:

$$a_i = \frac{1}{N}\sum_{y}\sum_{x} I_i(x,y)\cdot \qquad (7)$$

The chromatic distribution of the locally averaged image should be neutralized to reduce the influence of the dominant chromaticity of the image. Thus, the locally averaged image is divided by the average chromaticity and multiplied by the chromaticity value of estimated illuminant for each channels preserving the intensity for each channel as follows:

$$\begin{aligned}
L_{red,s}(x,y) &= \{F_s(x,y) * I_{red}(x,y)\} \times \frac{a_{green}}{a_{red}}\frac{c_{red}}{c_{green}},\\
L_{green,s}(x,y) &= \{F_s(x,y) * I_{green}(x,y)\},\\
L_{blue,s}(x,y) &= \{F_s(x,y) * I_{blue}(x,y)\} \times \frac{a_{green}}{a_{blue}}\frac{c_{blue}}{c_{green}},
\end{aligned} \qquad (8)$$

where c represents the chromaticity of the estimated illuminant. Then, the chromatic distribution of the locally averaged image is shifted toward the chromaticity value of the estimated illuminant within highlight region. However, the resulting image of retinex algorithm by large scale Gaussian filter has more information for chromaticity, while the resulting image of retinex algorithm by small scale Gaussian filter has less chromaticity and more detail. Thus the shifting ratio is controlled by the scale of the Gaussian filter as follows:

$$\begin{aligned}
L'_{red,s}(x,y) &= (1-\gamma_s) \times \{F_s(x,y) * I_{red}(x,y)\} + \gamma_s \times L_{red,s}(x,y),\\
L'_{green,s}(x,y) &= L_{green,s}(x,y),\\
L'_{blue,s}(x,y) &= (1-\gamma_s) \times \{F_s(x,y) * I_{blue}(x,y)\} + \gamma_s \times L_{blue,s}(x,y),
\end{aligned} \qquad (9)$$

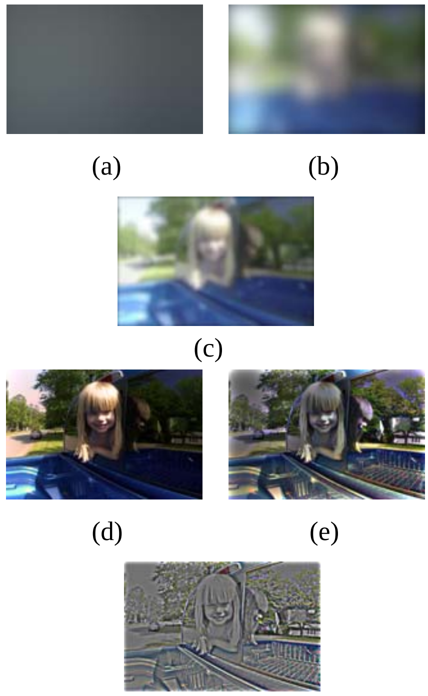


Fig. 2: In multi-scaled retinex process, resulting images of single scale retinex with (a) small scale, (b) middle scale, and (c) large scale, and Gaussian filtered images for (d) small scale, (e) middle scale, and (f) large scale.

where γ_s is the shifting ratio depending the scale of the Gaussian filter. Then, chromatic distributions of Gaussian filtered images are then corrected toward the estimated chromaticity of illuminant. Lastly, to enhance the local contrast, the resulting image is obtained by weighted sum of the difference images between the image and modified Gaussian filtered images in logarithmic space, as follows:

$$R_i(x,y) = \sum_{s=1}^{S} \omega_n \{\log I_i(x,y) - \log L'_{i,s}(x,y)\} \qquad (10)$$

Although the undesirable color distortion is corrected via correcting the local average image, the saturation of the resulting image is still lower than that of the original image, as the output of the retinex when using a small-scale Gaussian filter has a very low saturation. Thus, to restore the low saturation, the chroma is compensated with comparing the result of single retinex using large-scale Gaussian filter in CIELAB color space[7], as follows,

$$\hat{C}^{*MSR}_{ab} = C^{*MSR}_{ab} + (C^{*L}_{ab} - C^{*MSR}_{ab})\,. \qquad (11)$$

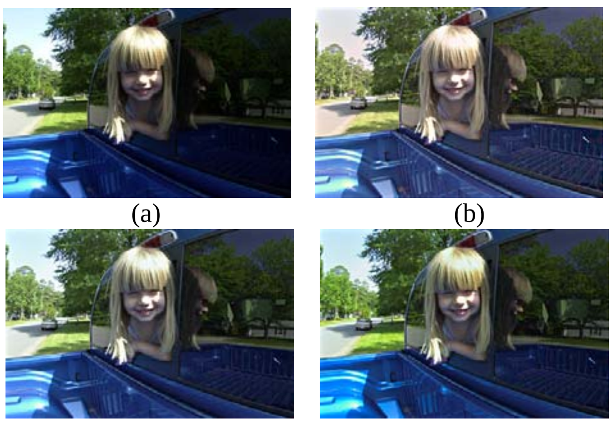
4. EXPERIMENTS

The result of multi-scaled retinex is very sensitive to the scale parameter of the Gaussian filter, σ_n, and the weight, ω_n, in Eq. (3). Thus the locally averaged images using parameters, $\sigma_n = (5, 20, 240)$, proposed by Jobson was used for stabilizing and enhancing the result of the process and the weight, $\omega_n = (0.3, 0.1, 0.6)$, is applied to reduce the halos in the resulting image for good color rendition[3,6].

Fig. 3, 4, and 5 shows the original image and resulting images by the multi-scaled retinex, proposed method, and proposed method with chroma compensation process. The chromatic distribution of original image, Fig. 3(a), is dominant on the blue and green. Thus, in Fig. 3(b), the resulting image of the multi-scaled retinex seems that it is a little added the chromaticity value of magenta over all although the detail is good represented in the window. Especially the color of the sky and the load is shifted toward the magenta. In contrast, the resulting image of proposed method without chroma compensation process, Fig. 3(c), the color of sky and load is not shifted to the magenta color enhancing the detail in region of the window. In the resulting image by proposed method with chroma compensation, Fig. 3(d), the saturation preserving lightness and hue is recovered without color distortion. In contrast, the chromatic distribution of the original image, Fig. 4(a), is dominant on the red color. Therefore, in the resulting image by multi-scaled retinex, Fig. 4(b), colors of skin and color chart are changed into the blue or green color. However, in the resulting image by proposed method, Fig. 4(c), colors of the skin and color chart are preserved without color distortion. In addition, in Fig. 4(d), the saturation is increased.

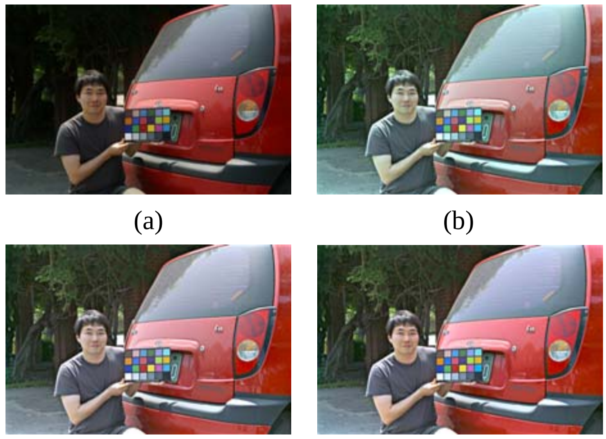
4. CONCLUSION

Multi-scaled retinex algorithm is usually used to enhance the contrast of shadow region in an image. Its performance is better than the performance of other methods, such as histogram equalization and gamma curve correction. However, as the multi-scaled retinex is based on Gray world assumption, the color distortion might be generated if the chromatic distribution of the image is dominant to certain chromaticity. To prevent the color distortion, the multi-scaled retinex algorithm is modified using the chromaticity of the highlight region. Additionally, the low saturation of results from multi-scaled retinex is compensated in CIELAB color space. In experiments, the proposed method shows a good performance both local contrast enhancement and color rendition without color distortion.



(a) (b) (c) (d)

Figure 3. “blue-car” image with (a) original image, (b) multi-scaled retinex, (c) proposed method without chroma compensation, and (d) proposed method with chroma compensation.



(a) (b) (c) (d)

Figure 4. “red-car” image with (a) original image, (b) multi-scaled retinex, (c) proposed method without chroma compensation, and (d) proposed method with chroma compensation.

5. REFERENCES

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