Skin Color Based Lightness Correction Method for Digital Color Images

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Abstract

We developed a new method for correcting lightness in images in response to the fact that people are most critical about the color of human skin in photographs, and other forms of image reproduction.

Conventional methods that are based on color distribution of an image can finely correct the lightness of most of the image, but cannot always finely correct the lightness of the skin. An image with an inappropriate skin lightness is not always evaluated highly, even if the lightness of the entire image is acceptable, because we pay special attention to skin color.[1]

We focused on the fact that the accuracy required to reproduce the lightness of the skin and an entire image is different. We think that deviation from the optimal lightness of skin color seriously affects perception, while deviation of an entire image has much less effect. Therefore, images with people can be further enhanced by adjusting lightness according to the difference between the actual lightness and the optimal lightness of skin color after the lightness has been corrected on the basis of color distribution. We developed a lightness correction method based on this phenomenon.

We evaluated our method by visual assessment. The results reveal that the performance of our method is superior to conventional methods.

Introduction

We developed a lightness correction method as part of an image enhancing process. The targets of this method are images with people, which are quite common among consumer photographs.

Recently, digital cameras have become very popular. However, ordinary users often take unusual photographs. For example, in cloudy weather, in a room, and in counterlight, we often take photographs that have inappropriate lightness.

The histogram equalization method, which is well-known for the method of lightness correction based on the color distribution of an image, is often used to correct inappropriate lightness in an image. Another method,[2] which is an improved histogram equalization method, has been reported. This improved method comes very close in effectively correcting the lightness of an image.

This method, however, often cannot satisfactorily correct the lightness of an image containing people. This is because the method corrects the lightness of the image without considering the lightness of the skin, which is specially noted by observers.

Conversely, if the lightness of the skin is correctly reproduced in images with people, we think that the image is highly evaluated by observers even if the lightness of the entire image is less correctly reproduced.

Hence, we developed a lightness correction method based on skin color, which gives a favorable impression to viewers. The method modifies the entire lightness of an image by optimizing the lightness of the skin within a range that does not adversely affect the lightness of the image.

Outline of Our Method

The kind of person in an image and the location of the person's skin in the image are necessary for our lightness correction method. Therefore in this development, we require simple tasks of the operator to correct the images.

Specifically, our method displays the image to be corrected, and the operator selects the race and gender of a person in the image and selects several points on the person's skin. Our method then corrects the lightness of the image in two steps. Each of the steps consists of an independent method.

STEP-A: The image is corrected by a method based on the color distribution of the image.

STEP-B: The image is further corrected by paying special attention to skin color.

In STEP-A, we employ the method given in reference 2. In this step, lightness is roughly corrected.

In STEP-B, the lightness of the image is corrected by the method based on skin color that is discussed here. The next chapter gives details of this method.

Processes of STEP-B

The lightness correction method of STEP-B does as follows.

STEP B-1:

Skin region is determined from the locations selected by the operator using the region growing method.[3]

STEP B-2:

An average color (called the standard correction color) of the skin region determined in STEP B-1 is calculated.

STEP B-3:

An optimal color is obtained from a database of optimal colors in accordance with the selection result of the person's race and gender in the image.

STEP B-4:

An amount of temporary lightness correction is calculated from the difference of lightness between the standard correction color and the optimal color. Then, the amount of final lightness correction is calculated by decreasing the amount of temporary lightness correction.

STEP B-5:

A function that adds the amount of final lightness correction to the lightness of the standard correction color is generated. Then the function modifies the entire image.

The details of each step are given below.

STEP B-1: Extract the Skin Region

Detailed descriptions of the skin region extraction process are as follows.

1) The region growth begins at each location selected by the operator.
2) Each pixel around the starting point that satisfies equation (1) is combined into the region.
3) If a pixel is combined into the region, each pixel around that pixel is evaluated. If it satisfies equation (1), it is also combined into the region.
4) Process 3) is repeated until there are no more pixels to be combined. In this way, a part of the skin region is generated.

$$\sqrt{\left(\frac{L_p^* - L_e^*}{1.5}\right)^2 + \left(a_p^* - a_e^*\right)^2 + \left(b_p^* - b_e^*\right)^2} < 10.0 \qquad (1)$$

(L^*_p, a^*_p, b^*_p): $L^*a^*b^*$ values that is converted from the RGB values of a pixel at the starting point.
(L^*_e, a^*_e, b^*_e): $L^*a^*b^*$ values that is converted from the RGB values of a pixel that is evaluated for addition into the region.
Note: Conversion of RGB values to $L^*a^*b^*$ values is based on the characteristics of the output device.

Parts of the skin region are generated from other locations, too. Finally, the skin region of the person in the image is formed by combining all parts of the skin region.

STEP B-2: Calculate the Average Value of the Skin Region

In this step, an average $L^*a^*b^*$ values of all pixels of the skin region (called the standard correction color (L^*_s, a^*_s, b^*_s)) are calculated. These values represent the color of the skin region. The $L^*a^*b^*$ values of each pixel are converted from the RGB values of each pixel.

Because lightness is corrected in the RGB color space, the RGB values (R_s, G_s, B_s) of the standard correction color are calculated from (L^*_s, a^*_s, b^*_s).

STEP B-3: Obtain optimal color

The optimal color (L^*_o, a^*_o, b^*_o) is obtained from a database containing preferable skin colors for each race and gender. To construct the database, we used commercial image collections of humans taken in a film studio with good illumination. The skins in the images are reproduced well, and their colors can be regarded as being preferable colors. We isolated the skin regions in images such as Fig. 1 by manual operation, then calculate the average color of all pixels of the skin region.

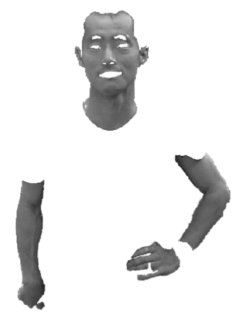

Figure 1. The skin region was isolated

We used 167 images of Mongoloid women and 169 images of Mongoloid men. For each image, we calculated average color of skin region. Then we calculated an average of 167 average colors of Mongoloid women and an average of 169 average colors of Mongoloid men. These two colors are stored in the database.

We have not yet gotten the optimal colors for other races.

STEP B-4: Calculate amount of final lightness correction

In this step, the amount of final lightness correction D_{fin} is calculated. D_{fin} is used for correcting the entire image so that lightness L^*_s of the standard correction color approaches lightness L^*_o of the optimal color, and the lightness of the entire image is not changed too much.

At first, the amount of temporary lightness correction D_{tmp} is calculated in accordance with equation (2).

$$D_{tmp} = L_o^* - L_s^* \qquad (2)$$

D_{tmp} is the difference between the lightness of the standard correction color and the lightness of the optimal color in the image. If the entire image corrected in STEP-A is recorrected in accordance with D_{tmp}, the lightness of the skin of the person in the image becomes optimal. Although the lightness of the entire image after recorrection is different from the lightness of the entire image corrected in STEP-A, we can usually get a more favorable lightness.

However, for example, if an image with people is taken in counterlight, the value of D_{tmp} becomes very large, such as 30. In this case, the lightness of areas other than the skin region changes excessively, even if the lightness of the skin region is finely corrected. The result is that the entire image is not highly evaluated.

Therefore, if the absolute value of D_{tmp} is small, we employ D_{tmp} as D_{fin} without any change. If the absolute value of D_{tmp} is large, we calculate D_{fin} by decreasing the absolute value of D_{tmp}. In the latter case, D_{fin} partially corrects the lightness of the skin, without excessively changing the lightness of the entire image. Therefore, a function for calculating D_{fin} from D_{tmp} should approximate the equation y=x when x is small, and the function should approximate the equation y=static when x is large. We chose equation 3 as a function that satisfies the above condition.

$$|D_{fin}| = |D_{tmp}| - \frac{1}{4 \cdot LIM}(D_{tmp})^2 ....(|D_{tmp}| < 2 \cdot LIM) \quad (3)$$
$$|D_{fin}| = LIM ....(|D_{tmp}| \geq 2 \cdot LIM)$$

The sign of D_{fin} is made equal to D_{tmp}.
LIM = 20 (decided by preliminary experiment)

A graph of equation 3 is shown in Fig. 2.

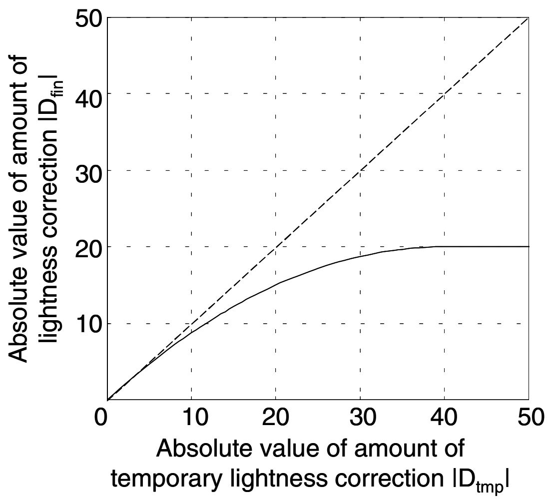

Figure 2. Function that decreases the amount of temporary lightness correction

STEP B-5 Modify the Entire Image

In this step, function f(x) for modifying the entire image is generated. F(x) is applied to the RGB values. The requirements for f(x) are as follows.

(1) An absolute value of modification amount |f(x)-x| becomes maximum in the vicinity of the standard correction color.
(2) F(x) is smooth.
(3) The lightness value of a modified standard correction color (R'_s, G'_s, B'_s), which is shown in equation 4, equals $L^*_s + D_{fin}$.

$$(R'_S, G'_S, B'_S) = (f(R_S), f(G_S), f(B_S)) \quad (4)$$

We set requirement 1 to keep the total modification amount of the entire image small.

A gamma function is often used for modifying RGB values. However, it cannot achieve requirement 1, because the modification amount of the mid-range colors is much larger than the modification amount of the standard correction color when the standard correction color is bright. For example, the maximum modification amount of a gamma function $g(x)=x^{2.92}$, which changes from 224 to 174 (g(224)=174), is 96.8 at 146 (g(146)=49.2). In this instance, the maximum modification amount becomes twice that of the modification amount of the standard correction color.

However, the modification amount of any color is rarely larger than the modification amount of the standard correction color if the standard correction color is dark. So, we employ the gamma function (equation 5) for correcting RGB values if the standard correction color is dark. We employ a function (equation 6), which is point symmetry of the gamma function at (x,y)=(127.5,127.5), if the standard correction color is bright.

Consequently, a function (equation 7) that is a combination of the two functions (equation 5,6) can achieve the requirement 1. (The value of k is small value when the standard correction color is dark and k is large when the standard correction color is bright. The equation for determining k is shown below.) Requirement 2 is satisfied because both functions (equations 5 and 6) are smooth.

$$f_a(\gamma_1, x) = 255\left(\frac{x}{255}\right)^{\gamma_1} \quad (5)$$

$$f_b(\gamma_2, x) = 255\left(1 - \left(1 - \frac{x}{255}\right)^{\gamma_2}\right) \quad (6)$$

$$f'(\gamma_1, \gamma_2, k, x) = f_a(\gamma_1, x) \cdot \left(1 - \frac{k}{255}\right) + f_b(\gamma_2, x) \cdot \left(\frac{k}{255}\right) \quad (7)$$

Next, we determine coefficient γ_1 and γ_2 for achieving requirement 3 by applying the bisection method to equation 8 and 9, respectively.

$$L^*_{SNF} = D_{fin} + L^*_s \quad (8)$$
$$R_{SNF} = f_a(\gamma_1, R_S), G_{SNF} = f_a(\gamma_1, G_S), B_{SNF} = f_a(\gamma_1, B_S)$$

L^*_{SNF} is the value of $L^*a^*b^*$ converted from values (R_{SNF}, G_{SNF}, B_{SNF}).

$$L^*_{SNB} = D_{fin} + L^*_s \quad (9)$$
$$R_{SNB} = f_b(\gamma_2, R_S), G_{SNB} = f_b(\gamma_2, G_S), B_{SNB} = f_b(\gamma_2, B_S)$$

L^*_{SNB} is the value of $L^*a^*b^*$ converted from values (R_{SNB}, G_{SNB}, B_{SNB}).

Finally, the actual value of k is determined and the RGB values of the entire image (R_i, G_i, B_i) are modified in accordance with equation 10.

$$k = \left(\frac{R_S + G_S + B_S}{3}\right) \quad (10)$$
$$RGB_{iN} = f'(\gamma_1, \gamma_2, k, RGB_i)$$

RGBi: one value (R_i, G_i, B_i)
RGBiN: one converted value (R_i, G_i, B_i)

Visual Assessment

We performed following experiment to confirm that our lightness correction method based on skin color is effective.

We prepared proper white balanced images containing people by manually removing colorcast from images taken with digital cameras. From these images, we generated images (a) by the correction method of STEP-A. From these images (a), we generated images (b) by the correction method of STEP-B.

We then displayed a pair of images (a and b) on a CRT display side-by-side, and asked observers to select the preferred one. We then calculated the Z-Score from the result of assessment by Thurstone's method of paired comparison[4]. Finally, we calculated the average Z-Score value, and its 95% confidence limit.

The conditions of visual assessment were as follows:

- -Number of images: 50 (male: 25, female: 25)
- -Number of observers: 10
- -CRT display: BARCO Reference Calibrator Plus
- -Display color temperature: 6500K
- -Display gamma: 2.2

The results of the assessment are shown in Fig. 3.

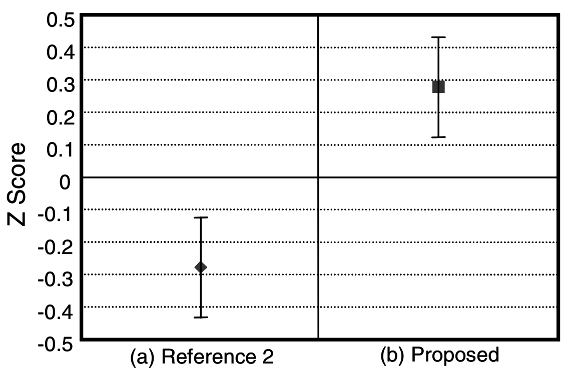

Figure 3. Results of visual assessment

The experimental results revealed that images (b) are more favorable than images (a). Hence, we confirmed the effectiveness of the lightness correction method based on skin color that additionally modifies the image modified by the conventional method based on color distribution.

Conclusion

We developed a lightness correction method for images containing people that can especially enhance the lightness of skin and also maintain the correct lightness of the entire image.

(1) We proposed a lightness correction method that combines a lightness correction algorithm based on color distribution with a lightness correction algorithm based on skin color.

(2) We proposed a lightness correction algorithm based on skin color that accurately corrects lightness of an image by using information of race and gender of the person and the locations of skin in the image.

(3) By using collections of commercial images, we determined the optimal color for Mongoloid male and female.

(4) We confirmed that the images corrected by our method gave more favorable impressions than the images corrected by a method based on color distribution.

References

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Biographies

Satoshi Semba received the B.S. degree in Electronic Engineering from Saitama University, Saitama, Japan in 1993. He joined Fujitsu Laboratories Ltd., Atsugi, Japan in 1993 and has been engaged in the research and development of color imaging technology and devices.

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