Selective Skin Tone Reproduction based on Multiple Preferred Skin Colors

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Abstract

Human skin in a color image is important and interesting visual object. since skin color is a key memory color in color application systems color reproduction for skin tone. Previous studies suggested skin color reproduction by mapping only to the center value of preferred skin region. However, it is not suitable to determine one preference color because preference color from the observer's preference test is not dominant. In this paper, skin color reproduction using multiple preferred skin colors for each race is proposed. The proposed method first defines multiple preferred skin colors for each race according to their luminance level. Then, the race is selected by calculating distance between average chromaticity of detected region and that of each racial skin from the database to assign preferred skin color for each race. Next, one of multiple preferred skin colors is selected for each selected race. Finally, input skin color is proportionally mapped toward preferred skin color according to the difference between input skin color and preferred skin color, smoothly reproducing skin color. Through the experimental results, the proposed method achieves preferred skin color reproduction for each race in an image including single race and races.

Introduction

The observer's preference is an important measure for image quality evaluation. The preference indicates the degree of satisfaction of an observer with respect to an image. Generally, preference is enhanced by reproducing the colors of sky, grass, and skin[1]. Among these colors, skin color is one of main factors in the preferred color reproduction, because eyes firstly perceived persons in an image, recognizing the skin color[2],[3]. Therefore, it is necessary that the skin color is corrected so as to become more natural for viewers.

Typically, preference color is determined by observer's preference test. As follows, the users evaluate better colors of a reproduced image than those of an original. Accordingly, the image quality can be improved effectively by transforming the skin color in images to the preferred skin color.

Various skin color reproduction methods have been proposed. Kao proposed directly color reproduction using color transformation matrix[4]. Sanger modeled the preferred skin color area with an ellipse and proposed the three preferred skin color ellipses according to the ethic group of Mongoloid, Caucasian, and Negroid[2]. Yendrikhovskij proposed the enhancement of perceived naturalness using comparison between the reproduced color and the preference colors[5]. Kim proposed mapping toward the preferred skin color region by the affine transform[6]. However, their studies are limited on mapping skin tones of different races to single tone in image and detected skin tone is mapped only to the center value of preferred skin region.

In this paper, skin tone reproduction based on multiple preferred skin color is proposed. The proposed method first defined preferred skin color as four for each race according to the luminance by using distribution of preference skin color. Next, race is selected by calculating Euclidean distance of average chromaticity between detected region and each racial skin from database. Then, each corresponding preferred skin color is determined for each selected race. The new mapping method is applied with weights calculated from not only the distance between skin tone of detected region and preferred skin tone but also the distribution of preferred color. Finally, input skin color is proportionally mapped toward preferred skin color according to the difference between input skin color and preferred skin color to smoothly reproducing skin color. In the experimental results, the proposed method achieves preferred skin color reproduction for each race in an image including single race and races.

Definition of preferred skin color

To evaluate the chromaticities distribution of preferred skin color for races, we preformed observer's preference test using printed facial images. First, we made a series of 100 to 180 facial images according to the luminance level. The results were printed out to produce the sample series of skin color in facial images. The number of printed facial images was 180 per each luminance level in image. After that, the preferred skin color in series of printed images was evaluated by observer's rating experiment. The experiment test involved 94 observers, 32 females and 62 males, aged 20-34. The test was conducted with standard viewing condition(D65). Figure 1 shows the sample of 180 facial images in luminance level of 0.7. The observers give the grade for five preferred skin color per each race in facial images. The grade indexed by 5, 4, 3, 2, and 1, respectively. As a result, top 4 of facial images generally have 30 percent of total scores. Afterwards, the chromaticities of preferred skin color were measured with spectrophotometer to transform other color spaces. We use YCbCr color space, because this color space enables to separate correction of luminance and chrominance.

Skin color detection

Most previous research on skin-color-based skin detection is based on the RGB, YCbCr, and HS color spaces[7,8,9]. However, these spaces produce different results according to different thresholds, making face detection by skin color detection difficult using geometric information. Therefore, this paper presents an efficient skin color detection method that combines the color spaces and a feature map, since most images of humans are focused on the people. As a result, the skin detection accuracy is

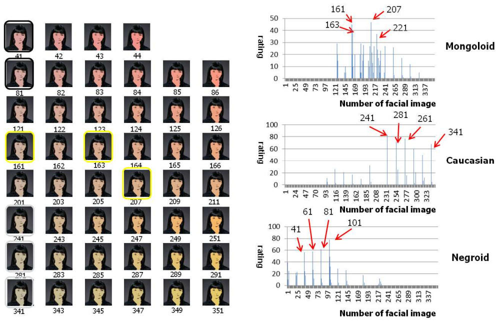


Figure 1. The sample of 180 facial images in luminance level 0.7 and the result of preference test.

improved. In the proposed method, a skin candidate region is first determined using the skin detection ratio of the RGB, YCbCr, and HSV color spaces. To calculate the TP(true positive) and FP(false positive), methods using RGB, YCbCr, and HSV color space were applied to 50 images. Table 1 shows the TP and FP results. The TP and FP are then applied to the methods using each color space. A skin candidate region $c(x, y)$ is calculated.

$$c(x,y) = D_1 w_1(x,y) + D_2 w_2(x,y) + D_3 w_3(x,y) \tag{1}$$

$$w_x = \frac{TP_x}{FP_x}, \quad x = 1,2,3 \tag{2}$$

where D_1, D_2, and D_3 represent the skin regions detected using RGB, YCbCr, and HSV color space, respectively. The weight w_x is the TR/FR ratio when using the color space based method. Subscript x represents the RGB, YCbCr, and HSV color space methods, sequentially. Next, we adapted threshold in detected region of each color spaces, and detected skin-color region when it is over the threshold T .

$$c'(x,y) \begin{cases} 1, & c(x,y) \geq T \\ 0, & c(x,y) < T \end{cases} \tag{3}$$

where the threshold T was obtained empirically.

A feature map is then generated based on the following steps. First, the GLV(gray level variance) is used as a way to measure the focus. The image is divided into $n \times n$ blocks. This process is shown in figure 2. The GLV is calculated as follows.

$$GLV(i,j) = \frac{1}{N} \sum_{p(x,y) \in U(i,j)} \left| g(x,y) - \mu_U(i,j) \right|^2 \tag{4}$$

where N is the number of pixels in each divided block, (x, y) and (i, j) represent a pixel in a divided block and the location of the block in the image, respectively, $\mu_U(i, j)$ shows the average gray level for the divided region, and $g(x, y)$ is the gray level for the current pixel. The GLV is used to detect a feature region. However, it is difficult to detect a skin color when only using features. Therefore, the feature map is compensated by filling. If there is a neighbor region, it is filled to construct another region, where the proposed requirement for filling a neighbor region is as follows: a feature region is determined when it has 3 neighbor regions.

Table 1. The TP, FP results using RGB, YCbCr, HSV color space

	RGB	YCbCr	HSV
Detected pixels in images	1968348	1613767	1484704
Detected pixels in skin images	1361924	1140094	1113450
Pixels of skin region	1546399	1546399	1546399
TP(true positive)	88%	74%	72%
FP(false positive)	31%	29%	25%

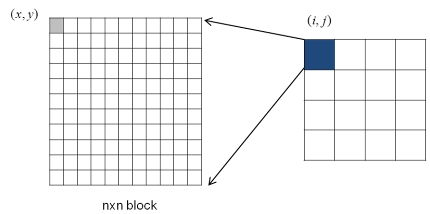


Figure 2. Feature detection process using nxn blocks.

Finally, a skin region is determined using both a skin candidate region and the feature map. The results are shown in figure 3. Table 2 compares the TR and FR when using the proposed and previous methods. The proposed method showed better detection results than the color space based methods.

Preferred skin color reproduction using selection of preferred skin color

Because previous skin tone reproduction methods chose one preferred color for skin color reproduction, it is hard to presenting those methods on images that have different kinds of races. Therefore, we proposed a method for considering the case that image including different kinds of races. First, race is selected for each skin detected region. After that preferred skin color is selected for each race in race selected areas. Then, skin color reproduction is preformed proportionally toward selected preferred skin color

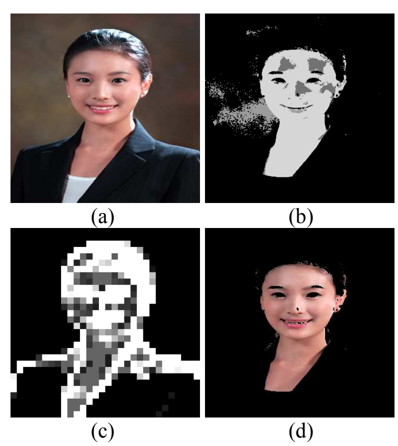


Figure 3. Skin color detection result using proposed method (a)original image, (b)skin candidate region, (c) feature map, (d) skin color detected image.

Table 2. Comparison of TP, FP results

	RGB	YCbCr	HSV	Proposed method using 5x5 block
Detected pixels in images	1968348	1613767	1484704	1534716
Detected pixels in skin images	1361924	1140094	1113450	1253174
Pixels of skin region	1546399	1546399	1546399	1546399
TP(true positive)	88%	74%	72%	81%
FP(false positive)	31%	29%	25%	18%

Race selection of detected skin region

To consider the case of image including races, race selection is performed by using luminance level and chromaticity in each skin detected area. First, detected skin region is classified by block using labeling algorithm. After that, average luminance level and chromaticity are calculated for each block and the average chromaticity according to luminance level of each race is calculated by using 200 human images in magazine. Next, Euclidean distances of average chromaticity between of block and of skin color for each race which have equal luminance level is calculated.

$$d_{r_n} = w_r\left[\left(Cb_{mb_n} - Cb_{mr_n}\right)^2 + \left(Cr_{mb_n} - Cr_{mr_n}\right)^2\right]^{1/2} \quad (5)$$

where r denote one of three races such as caucasian, mongoloid, and negroid. Cb_{mb_n} and Cr_{mb_n} is average chromaticity of detected skin region for each block. Cb_{mr_n} and Cr_{mr_n} is average chromaticity of skin color for each race. Subscript n is the number of total blocks for detected skin region. w_r is weight using distribution of skin for each race according to luminance level. Figure 4 shows classification of detected skin by blocks using labeling method. Table 3 present distribution of skin for each race according to luminance level. Then, race is selected by having minimum Euclidean distance of average chromaticity between of block and of skin color for each race which have equal luminance level.

$$S_{x_n} = \min_{r=1,2,3,4}[d_{r_n}] \quad (6)$$

To carry out the performance of race selection, true and false rate is calculated using 50 human images in magazine for each race. Table 4 present the true and false rates. As a result, the true rate of negroid is high. However, mongoloid and caucasian were found mixed together because of having similar distribution of skin chromaticity according to luminance level. Therefore, skin reproduction for negroid is performed by using 4 preferred skin color which is selected by preference test according to different luminance level. Skin reproduction for caucasian and mongoloid is performed by using 8 preferred skin color which is top 4 of preferred skin color for each race.

Table 3. Distribution of skin for each race according to luminance level

Mongoloid			Caucasian			Negroid		
lightness	pixels	distribution	lightness	pixels	distribution	lightness	pixels	distribution
0	151	0%	0	2	0%	0	71304	2%
0.1	5233	0%	0.1	131	0%	0.1	449598	15%
0.2	69243	2%	0.2	7868	0%	0.2	661414	22%
0.3	266287	7%	0.3	113503	3%	0.3	577579	19%
0.4	507126	14%	0.4	335451	9%	0.4	483881	16%
0.5	689717	19%	0.5	572819	16%	0.5	332433	11%
0.6	734355	20%	0.6	687160	19%	0.6	196735	6%
0.7	652555	18%	0.7	722907	20%	0.7	108303	4%
0.8	381624	11%	0.8	613556	17%	0.8	69609	2%
0.9	201873	6%	0.9	388748	11%	0.9	48243	2%
1.0	83586	2%	1.0	147399	4%	1.0	52608	2%

Table 4. The true and false rates of race selection

	Total blocks	True	False	True rate
Caucasian	71	44	27	62%
Mongoloid	76	43	33	57%
Negroid	73	60	13	82%

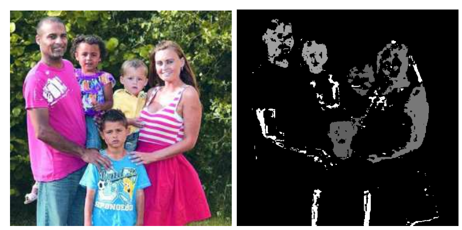


Figure 4. Classification of detected skin by blocks using labeling method.

Selection of preferred skin color according to input skin color

Generally skin color reproduction is performed by defining the preferred skin color and mapping proportionally toward preferred skin color. However, it is difficult to present one of preferred skin color. Preferred rate of skin color is evenly distributed in top 4 skin color as in preference test of skin color. Therefore, we are proposed mapping to corresponding preference skin color for each selected race of detected region. First, race is selected for each skin detected region. After that preferred skin color is selected among top 4 skin color for selected race. Figure 5 shows corresponding preferred skin color selection for negroid. Then, skin color reproduction is preformed proportionally toward selected preferred skin color. Selection of preferred skin color is divided into two cases through race selection rate. If skin detected block including input pixel is selected negroid, then preferred skin color for negoid is selected by having minimum Euclidean distance between average chromaticity of block and top 4 of preferred skin color for negroid which have equal luminance level. Preferred skin color selection is presented as follows.

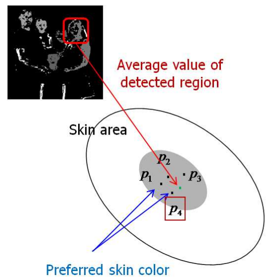


Figure 5. Corresponding preferred skin color selection for negroid.

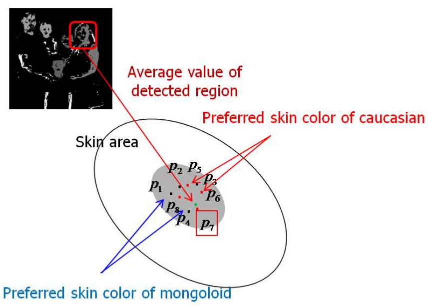


Figure 6. preferred skin color selection for caucasian and mongoloid.

First, Euclidean distances of average chromaticity between of block and of multiple preferred skin colors for selected race which have equal luminance level is calculated.

$$d_{p_x} = w_{p_x}\sqrt{\left(Cb_{p_x} - Cb_{mb}\right)^2 + \left(Cr_{p_x} - Cr_{mb}\right)^2} \qquad (7)$$

$$w_{p_x} = 1 + \left(1 - \frac{P_x\ count}{\max\ count}\right) \qquad (8)$$

where w_x is weight for top 4 of preferred skin color P_x. In other words, ratio of earned scores by preference test is used by weighting parameter. Cb_{mb} and Cr_{mb} present average chromaticity of skin detected block including input pixel. Cb_{P_x} and Cr_{P_x} present chromaticity of top 4 preferred skin color. d_{P_x} presents Euclidean distance between average chromaticity of skin detected block including input pixel and selected preferred skin color. Then, preferred skin color is selected by having minimum Euclidean distance of average chromaticity between of block and of multiple preferred skin colors for selected race which have equal luminance level.

$$S_{p_x} = \min_{x=1,2,3,4}[d_{p_x}] \qquad (9)$$

where S_{P_x} presents selected preferred skin color. If skin detected block including input pixel is selected caucasian or mongoloid, then the selection is performed by using 8 preferred skin color which is top 4 of preferred skin color for each race, because skin color of these races have similar distribution of skin chromaticity according to luminance level. Figure 6 shows corresponding preferred skin color selection for caucasian and mongoloid. In figure 6, black point is presented top 4 of preferred skin color for

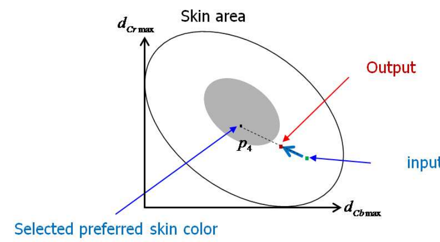


Figure 7. The skin color correction toward selected preferred skin color.

mongoloid and red point presents top 4 of preferred skin color for caucasian.

Skin color reproduction toward selected preferred skin color

Race selection and selection of preferred skin color are previously mentioned. Input skin color is proportionally mapped toward preferred skin color according to the difference between input skin color and preferred skin color to smoothly reproducing skin color. For example, if the difference between input and selected preferred skin color is small, then low rate is applied to reproduction toward selected preferred skin color. Figure 7 show the skin color reproduction toward selected preferred skin color. Finally, reproduced skin color Cb_o and Cr_o are obtained by using difference of selected preferred skin color and input skin color.

$$Cb_o = Cb_i + R_1(Cb_{S_{P_x}} - Cb_i) \qquad (10)$$

$$Cr_o = Cr_i + R_2(Cr_{S_{P_x}} - Cr_i) \qquad (11)$$

$$R_1 = \left|(Cb_{S_{P_x}} - Cb_i) / d_{Cb\max}\right|^2 \qquad (12)$$

$$R_2 = \left|(Cr_{S_{P_x}} - Cr_i) / d_{Cr\max}\right|^2 \qquad (13)$$

where Cb_o and Cr_o present reproduced skin color. Cb_i and Cr_i present input skin color. $Cb_{S_{P_x}}$ and $Cr_{S_{P_x}}$ present selected preferred skin color for each detected block. R_1 and R_2 are nonlinear weight function for smoothing reproduction using $d_{Cb\max}$ and $d_{Cr\max}$. $d_{Cb\max}$ and $d_{Cr\max}$ are maximum difference of Cb and Cr in skin region.

Experimental result

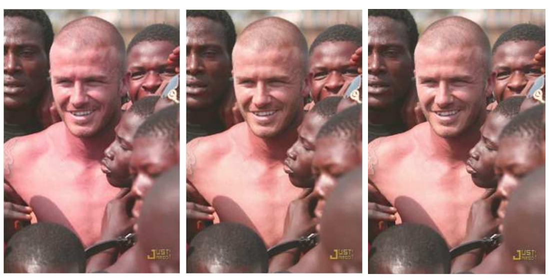
To carry out an experimental evaluation for the proposed algorithm, observer's preference test is performed. The subjective evaluation test involved 45 observers, 15 females and 30 males, aged 24-34. The eyesight of the observers was either normal or corrected with glasses, and the test was conducted in standard viewing condition(D65).In experiments, we use images including single race and races. Figure 8 and figure 9 show a comparison of the skin tone reproduction result for image including single race. Figure 10 shows a comparison of the skin tone reproduction result for image including races. The observers were then asked to rank the corrected images by their preference considering the correction for each race. Each observer judged each pair of corrected images and assigned 1 to the selected image and 0 to the rejected image. In the case of a tie, 0.5 was assigned to each image. The scores were

(a) (b) (c)

Figure 8. The original and resulting image by proposed method using image including sing race; (a) the original image; (b) the conventional method; (c) the proposed method.

(a) (b) (c)

Figure 9. The original and resulting image by proposed method using image including sing race; (a) the original image; (b) the conventional method; (c) the proposed method.



(a) (b) (c)

Figure 10. The original and resulting image by proposed method using image including several races; (a) the original image; (b) the conventional method; (c) the proposed method.

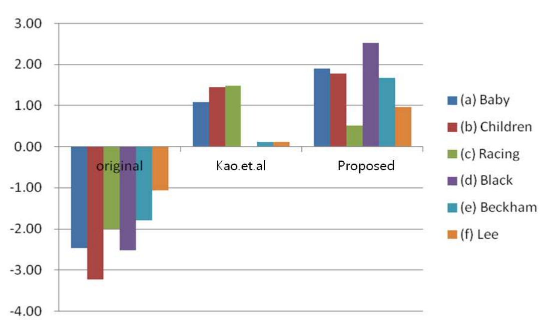


Figure 11. Z-scores for test images as a result of subjective evaluation.

then totaled and converted to a z-score[10]. The compared result is shown in figure 11. For the preference test, the z-scores for the proposed method were generally higher than those for Kao et al. As a result, proposed method achieves preferred skin color correction for each race on an image including singe race and races.

Conclusion

This paper propose preferred skin color reproduction based on multiple preferred skin colors from preference test. To achieve selection of preferred skin color for skin detected region, the proposed method is applied with weights calculated from not only the distance between skin tone of detected region and preferred skin tone, but also the distribution of preferred color. Differently from previous methods, using selection of among multiple preferred skin color in each block allows to reproduce the skin color in image including races. In the experimental results, the proposed method achieves preferred skin color reproduction for each race on an image including singe race and races.

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