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Skin Balancing: Skin Color-Based Calibration for Portrait Images to Enhance the Affective Quality

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Abstract

Because our sensitivity to human skin color leads to a precise chromatic adjustment, skin color has been considered a calibration target to enhance the quality of images that contain human faces. In this paper, we investigated the perceived quality of portrait images depending on how the target skin color is defined: measured, memory, digital, or CCT skin color variations. A user study was conducted; 24 participants assessed the quality of white-balanced portraits on five criteria: reality, naturalness, appropriateness, preference, and emotional enhancement. The results showed that the calibration using measured skin color best served the aspects of reality and naturalness. With regard to appropriateness and preference, digital skin color obtained the highest score. Also, the memory skin color was appropriate to calibrate portraits with emotional enhancement. In addition, the other two CCT target colors enhanced the affective quality of portrait images, but the effect was quite marginal. In the foregoing, labelled Skin Balance, this study proposes a set of alternative targets for skin color, a simple but efficient way of reproducing portrait images with affective enhancement.

Introduction

Almost everyone has experienced portrait editing. It even becomes necessary before publishing any media content. With improvements in display, the necessary details of editing increase, along with our pursuit of image quality [1]. With the presets and filters of smartphone applications, anyone can obtain adjusted images by clicking once. Ironically, too many options, such as hundreds of filters and complicated adjustment bars, make the editing more confused.

Portrait editing is also difficult, even for experts [2]. Instead of presenting a vivid or contrasting image color, a proper color tone is necessary due to our sensitivity to memory colors, especially facial skin color [3]. Skin color is a typical memory color, and people have a common and clear idea of that color in mind. Typical memory colors include the blue of the sky, the green of grass and red of an apple [4]. Studies have revealed that people are especially strict on skin color, with a relatively low tolerance [3].

Because of the psychological and cognitive aspects, studies have paid attention to facilitating skin color to tackle the portrait enhancement. Bianco and Schettini developed an algorithm that exploits skin color to estimate and correct the scene illuminant and further improve the image's quality [5]. They used a portrait dataset filmed with a color checker as the reference. Similarly, Kim et al. also used preferred skin color as a standard for calibration [6]. In both studies, a choice of skin color for the reference is crucial for the portrait's enhancement.

This study intends to investigate whether the perceived image quality of calibrated portrait images is influenced by the choice of skin target. Furthermore, the study expects to provide empirical evidence of graphic practices that involve portrait images and their emotional expressions.

Objective

The aim of this study is to figure out the roles and the affective effect of Skin Balancing, which we claim is an alternative to the color calibration technique; Skin Balancing uses the skin colors as the target. In an image, Skin Balancing tries to convert the facial skin's color into the target skin color, so the balanced result depends highly on how the target color is defined. In this study, we considered six variations: four refer to previous studies, and the other two were added to cover a wide range of hue angles. Based on assessments, this study expects to offer an optimal target skin color in accordance with the emotional quality an image pursues.

Variations of target skin color

Skin color has long been an interest for studies outside of cosmetology or dermatology. Because human beings are very keen to the perception of the color of skin [3], studies related to human vision have paid great attention to objective and subjective qualities of viewing human skin color. Based on a literature review, we first organized skin targets into three categories: measured, memory, and digital skin colors. The measured skin target is the real skin color measured with a spectrophotometer. Studies have been conducted to see the differences in skin color by ethnicity or by country [7-9]. In general, skin color's brightness varies largely along the various ethnicities and marginally in hue. Secondly, the memory color of skin is recorded in our memory as more vivid [4]. Thirdly, when the skin target is decided in context of digital reproduction, two trends are discovered. One is the similar ratio of differences in redness and yellowness from the prior two types of target skin colors. In terms of CIELab, the preferred digital skin color has similar a* and b* values. The other trend is an increase in brightness, or a higher L*. In other words, portrait images displayed on media should appear brighter and paler to visually match our perception or memory of the skin colors [10-13]. In addition, the colors of portrait images on magazines and fashion portal sites are reproduced in diverse color temperatures. Therefore, this study added two more targets to explore the Skin Balance's affective effect based on a more diverse CCT range. To sum up, we employed 6 types of target skin colors, as presented in Table 1.

Table 1. Color setting of 6 target skins together with original sources and labelled categories.

No.	L*	a*	b*	C*	H*	Categories and [Sources]
1	60-65	12	17	21	55	Measured skin color [8]

2	60-65	11	22	25	63	Memory skin color [3, 4]
3	60-65	14	14	21	47	Preferred digital skin color [12]
4	70-75	10	9	13	42	
5	60-65	25	18	31	36	CCT variation (warm, cool)
6	60-65	10	-6	12	329	

Method

Skin Balance

In this study, we utilize skin color as a target to enhance the color performance of portrait images. The key concept of our approach was to first extract skin color from the current portrait that we wanted to process and then to calibrate it based on the difference between the current and target skin colors.

Three steps were followed for skin balancing. The first was detecting the current image's skin color. Faces in a portrait were detected using an existing object detection algorithm. In the RGB space, pixels that satisfied R> 95, G> 40, and B> 20 were extracted first. If the RGB components of these pixels are not close and the R components were the greatest, the pixels were finally marked as skin [14]. The portrait's skin color was then extracted by averaging these skin pixels.

The second step was setting up a target skin color. As mentioned earlier, we collected target skin colors from previous studies and considered six kinds of target skin color: (1) was optically measured, (2) were remembered in memory, (3) and (4) were reproduced on digital media, and (5) and (6) were CCT variations. In total, six target skin values were selected and listed in Table 1.

Finally, color transformation was performed. In each portrait image, the color adjustments were achieved with one gain factor and two offset factors. L^* adjustment is controlled by gain factor K_L. a^* adjustment is controlled by offset factor t_1. b^* adjustment is controlled by offset factor t_2.

$$K_L = L_{target} / L_{original} \quad (1)$$

$$t_1 = a_{target} - a_{original} \quad (2)$$

$$t_2 = b_{target} - b_{original} \quad (3)$$

Both offset and gain approaches can increase or decrease L* to achieve a higher or lower brightness. Differences appear in contrast. An offset factor for L increases or decreases the L*, changing brightness. A gain factor, however, does not only increase or decrease the brightness, it also increases or decreases the brightness contrast at the same time. For portraits of Asian people, a simple increase in brightness would decrease the perceived clearness and contrast. Therefore, a gain factor is considered for L*. The a* and b* range from -128 to +127. Due to the range of these two channels, only the offset factor is proper.

Going through the three steps, we changed the color of skin pixels to the target color we set. Because Skin Balance is globally applied to the whole image, the non-face area changed its color properties as well. The pixels of the non-face area followed the same amount of color shift. An example process from color extraction to color shift is shown in Figure 1. The adjusted picture on the right in Figure 1 is a result of Skin Balance targeting's measured skin color. Consequently, we generated six alternatives for each portrait image.

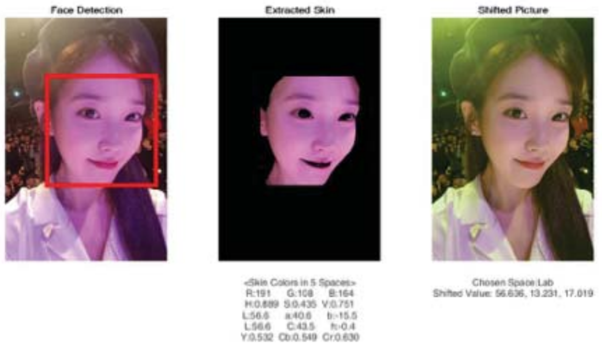

***Figure 1**. The Procedure of Skin Balancing: Skin color extraction and color adjustment targeting the measured skin color.*

Visual assessments

We conducted an experiment of visual assessments to examine whether the affective effect of Skin Balancing is influenced by the choice of a target skin color. We recruited 24 participants with an average age of 21.63. All of them were in normal color vision.

Six images of Asian people were selected from magazine websites, official government websites, and major search engines (Figure 2). People in the selected images include politicians, actors and actresses, and an everyman. Then, for each portrait image, the six variations that resulted from Skin Balancing (No.1 ~ No.6) were prepared as a portrait set (**Figure 3**) All participants were exposed to all the portrait sets in a random order. When a new portrait set was presented, the participants were asked to choose one or two portraits that best corresponded to the evaluation metrics.

***Figure 2**. Six original portrait images used in the user study.*

***Figure 3**. Example portrait images reproduced via six target skin colors.*

Metrics

When a set of six alternatives was presented, we asked participants to consider five evaluation criteria: reality, naturalness, appropriateness, preference, and emotional enhancement. As presented in Table 2, "reality" asked about which image looked most realistic. Among the five criteria, the first three ("reality", "naturalness", and "appropriateness") were to ensure the standard image quality [15]. We added the last two criteria ("preference" and "emotional enhancement") to identify the affective impact.

Table 2. Sample questions in user study.

Criteria	Questions	Reference
1	Select the image that is most similar with a scene in **reality**.	[15]
2	Select the image that is most **natural**.	[15]
3	If this image is used on the official website of Present Moon, which image is most **appropriate**?	[15]
4	Select the image that is most **preferred**.	[16, 17]
5	Select the image that conveys a certain **emotion**.	[2, 18]

Result

As Table 3 shows, we sorted the frequency data along the six types of Skin Balancing and the five criteria. Because we instructed the participants to choose one or two portrait images among six variations, the total number exceeds 144 (24 people × six portrait sets). For example, when asked to choose the most realistic look, most participants chose the Skin Balancing variation No.1 or No.3, which targeted measured skin color (selected 66 times) or digital skin color (selected 47 times), respectively. In this way, Table 3 displays the matches between the Skin Balancing type and the effective criteria. Overall, we observed that measured skin color and preferred digital skin colors were generally advocated across the five criteria. On the contrary, the CCT variations were overall not useful as the Skin Balance technique's target.

Table 3. Accumulated frequency while participants' viewed six sets of portraits. Participants selected 1 or 2 out of 6 variations regarding each of the criteria. (N = 24, 6 stimulus sets).

Criteria	Skin Balancing: Six variations of target skin color						
	1	2	3	4	5	6	Total
Real	66	26	47	28	0	5	172
Natural	56	19	63	9	0	0	147
Appropriate	19	16	64	57	4	16	176
Preferred	29	16	49	56	5	13	168
Emotional	21	44	30	19	32	30	176
Total	191	121	253	169	41	64	

To statistically examine the relationship between Skin Balancing types and criteria, we performed a Chi-square test based on the frequency data. The results showed a statistically significant relationship, indicating that variations of Skin Balancing are useful in optimally serving the target criteria [$\chi^2 = 243.06$, $p < 0.05$]. To be specific, portrait reproductions based on measured skin color (No.1) present a more real and natural image quality. Portrait reproductions based on preferred digital skin color (No.4; pale & bright) were the most preferred among all six alternatives. Furthermore, portrait reproductions based on preferred digital skin colors (No.3 & No.4) were most appropriate for certain content usage. Both No. 3 and No. 4 referred to two kinds of preferred digital skin colors, but No.3 was more vivid. Hence, these three variations of Skin Balancing should be useful to ensure a standard image quality for portraits. On the other side, portrait reproductions based on memory skin color (No.2) and warm (No.5) and cool (No.6) CCT variations appealed to emotional enhancement.

Conclusion

Previous studies prove that skin color is a crucial feature for the image enhancement of portraits. Consequently, the target skin color or the reference database for skin color is of great importance and necessary for better outcomes. This study proposed six target skin colors from biological, cognitive, affective, and practical aspects and evaluated how portrait reproductions based on these various target skin colors (Skin Balance) affects the perceived image quality. The study achieved two major findings. First, portrait reproductions based on measured and preferred skin color present a standard level of professional image quality. Furthermore, increased lightness makes portraits more attractive. Secondly, portraits reproduced based on memory skin color and skin color in diverse CCT variations present an emotional image quality.

This research is an initial stage for exploring target skin color for Asian portrait enhancement. Hence, more materials should be examined to improve the globalization of the database. For the next stage, we will expand the target skin colors to more ethnicities. Thus, a robust algorithm on ethnicity detection, skin region detection and a color adjustment based on the target skin color will be derived through a series of user tests. With this, possible plugins or tools for specific software or platforms could be established for massive portrait enhancements and editing.

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