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COLOR TRANSFER METHODS BASED ON DISTRIBUTION OF COLOR GRADATION AND KANSEI EVALUATION

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Abstract. *This study aims to aid the design of digital content based on an approach of KANSEI engineering. We propose a new color transfer method using the feature of gradation obtained from the color distribution of images. The purpose of color transfer is to make the meaning of the image more understandable by changing its color quality. To that end, we define a gradation plate which represents a feature of the color distribution in HSV color space. The color transfer involves such process as replacing the gradation plate of a target image with the gradation plate of the referred image which has the intended impression. We extracted the KANSEI words expressing the impression of images and conducted experiments to confirm that image impression certainly changes by the color transfer. Indeed, we found that the impression of the referred image is reflected in the target image after the color transfer. When the gradation plate is transferred, the impression is also transferred. Thus, we could assume that gradation could serve as features of KANSEI information.*
Keywords: Gradation of colors, 3-dimensional color space, Color transfer, KANSEI engineering

1. **Introduction.** Today, computers and the Internet have become so popular that users can easily create and transmit the digital contents. The creators/senders of digital contents may want to reflect their intension to various content elements such as design, color scheme and images as KANSEI information. The word of KANSEI is Japanese which means sensitivity, sensibility, or sensation and sentiment [1]. In the field of KANSEI engineering, it has been expected to apply the research outcomes to production of digital contents. Color has been considered to be one of the most significant design elements which affect human sensibilities. The design element of color plays an important role in expressing sensibility of image contents [2].

Especially, we have taken particular note of gradation as a typical coloring technique. In [3], we discussed methods for generating color gradation using the color distribution of an image. There, we assumed that the color gradation could represent the human impression. Then, in the subsequent paper [4], we proposed a novel color transfer method based on the color gradation. In this paper, we show the effectiveness of the color transfer

method through sensitivity evaluation experiments using the semantic differential technique method.

The purpose of color transfer is to make the meaning of the image more understandable by changing its color quality. To that end, we prepare an image with desirable color tone as a reference, and we transfer the color of the reference image to the target image. Gradation is a continuous change of color from a certain color to another. In [3], we regarded the gradation as color distribution (2-dimensional histogram) on a 2-dimensional manifold in a 3-dimensional color space. In general, the gradation is represented by the equation of the 2-dimensional manifold and the color distribution on the manifold. We call the 2-dimensional manifold a gradation plate. We assume that the 2-dimensional manifold is a plane in HSV color space for simplicity.

Outline of the color transfer algorithm [4] is as follows. First, we correct the gradation plate of the target image so as to be coincident with the gradation plate of the reference image. Further, we calculate the variance of the residual error when we approximate the color distribution by the gradation plate, and we correct the color distribution of the target image so that the residual error of the target image is coincident with that of the reference image. Then, we further correct the color distribution of the target image so as to be closer to that of reference image on the gradation plate.

There have been reported various methods of color transfer for such images as photographs and paintings [5-9]. Reinhard et al. proposed a method of color correction where color characteristics are borrowed from other images [5]. They compared the statistics of color in various color spaces. Greenfield and House proposed a recoloring method that correlates main colors using color palette [6]. These two methods transfer the color from the source image to the destination image based on the mean or the standard deviation of color. These methods are applied to color temperature transformation on a photograph of a sunset scene or to recoloring of paintings using palette color. The results are said to be acceptable subjectively.

However, it is a remaining issue to evaluate color transfer methods objectively. In this paper, we perform sensitivity evaluation experiments to evaluate the effectiveness of the color transfer method. More specifically, we show effectiveness of the method proposed in [4] through evaluation experiments based on the correspondence between gradation templates and KANSEI words.

We explain the method of color transfer based on gradation plate in the next section. Then, we explain the evaluation experiments of sensitivity and present experimental results in Section 3. In the last section of this paper, we draw conclusions from our experiments.

2. **Method of Color Transfer.**

We assume that the gradation plate is a plane in an HSV color space as mentioned in the last section. At first, we calculate the color histogram in the HSV color space. We express the HSV color space on a 3-dimensional Cartesian coordinate system. We avoid a cylindrical coordinate system or conical coordinate system because color resolution at lower saturation side is lower than higher saturation side when fitting a plane on the color distribution. Thus, we use the Cartesian coordinate system, where we assume that both ends at the hue coordinate are linked as a loop.

Method of color transfer is as follows. First, a clipped area is extracted from each of the object image and the reference image. Then, the color distribution is calculated in each clipped area and the gradation plate is obtained by fitting a plane to the color distribution. Also, the standard deviation of residuals when the color distribution is approximated by the gradation plate is calculated. The gradation plate and the standard deviation are used as the features representing the color distribution in the clipped area. The features of the object image are transferred so that they become similar to the features of the reference image.

2.1. **Transfer by the gradation plate.** The gradation plate is obtained by fitting the regression plane to the color distribution in HSV color space (see Figure 1). Standard deviation of residuals is also obtained. Since we found that the gradation plate is almost perpendicular to the hue axis in a preparatory experiment, the standard deviation of residuals is well approximated by the standard deviation of residuals along the hue axis.

Let $h = f_{obj}(s, v)$ and $h = f_{ref}(s, v)$ be the equations of the gradation plates of the object image and the reference image, respectively. Let σ_{obj} and σ_{ref} be the standard deviation of residuals of the object image and that of the reference image, respectively. Figure 2 shows how color transfer is performed. The color of the object image (h, s, v) is transformed to (h', s', v') as

$h' = \frac{\sigma_{ref}}{\sigma_{obj}}(h - f_{obj}(s, v)) + f_{ref}(s, v)$

$s' = s$

$v' = v$.

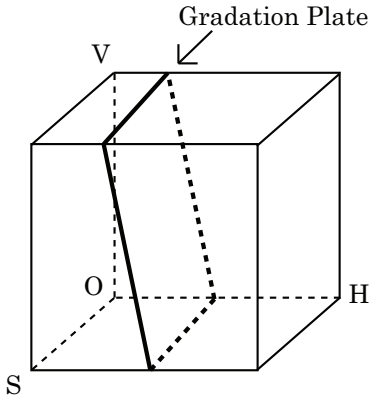

FIGURE 1. Conceptual diagram of gradation plate

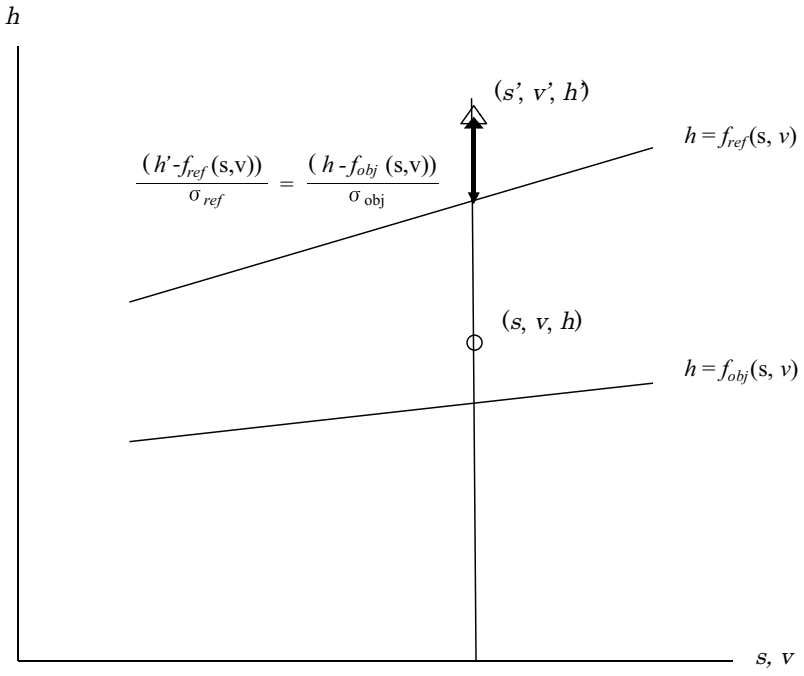

FIGURE 2. Transfer by the gradation plate

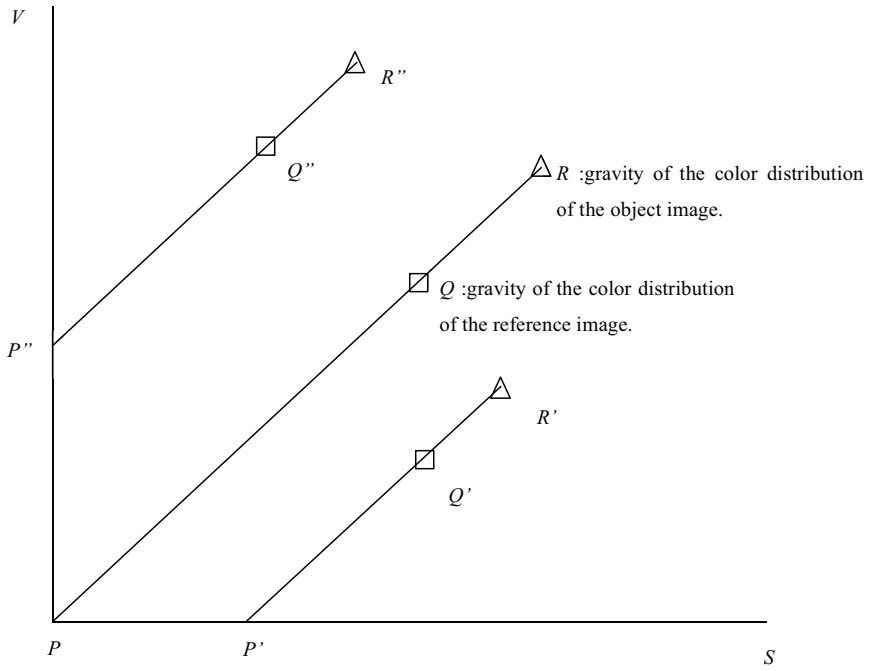

FIGURE 3. Transfer in the gradation plate

2.2. **Transfer in the gradation plate.** In the last subsection, color transfer is performed according to relation between the gradation plates of the object image and the reference image. Next, color transfer successively continues according to relation between the color distribution on the gradation plates of the object image and the reference image. Figure 3 shows how color transfer is performed. Since we assumed that gradation plate is almost perpendicular to the direction of hue axis, the color distribution on the gradation plate is approximated by the distribution of color components of s (saturation) and v (value). First, we calculate the gravity of the color distribution. We use the data which lies just along the diagonal line ($|s - v| < 0.05$) on the gradation plate. Incidentally, the maximum of $|s - v|$ is 1. The value 0.05 is determined pre-experimentally. In Figure 3, the point R denotes the gravity of the color distribution of the object image, and Q denotes the gravity of the color distribution of the reference image. Let λ be the ratio of the gradation gravity of the object image to the gradation gravity of the reference image. That is $\lambda = PQ/PR$. The color transfer on the gradation plate is performed so that $P'Q'/P'R' = \lambda$ or $P''Q''/P''R'' = \lambda$. More specifically, the color of the object image (h', s', v') which is obtained in the last subsection is transformed to (h'', s'', v'') as

$h'' = h'$
$s'' = \lambda s'$
$v'' = v' - s' + s''$
when $s' < v'$, and
$h'' = h'$;
$s'' = s' - v' + v''$
$v'' = \lambda v'$
when $s' \geq v'$.

3. **Experiments.** We conduct experiments to confirm that the impression of the reference image can be well transferred to the object image through the color transfer proposed in this paper. Specifically, we examine how sensibility evaluation of the image changes

when the color of the object image is transferred using the gradation feature of reference image, and consider how the gradation feature affects sensibility evaluation of image. If the sensitivity evaluation of the image after the color transfer becomes closer to the sensitivity evaluation of the reference image, we can conclude that impression of the image is successfully transferred from the reference image to the object image.

In this experiment, we design two kinds of sensibility evaluation. One is a qualitative evaluation and the other is a quantitative evaluation. In the qualitative evaluation, sensibility words (KANSEI words) are extracted as keywords for each image. If the image after the color transfer and the reference image have common keywords, impression or sensitivity of image is considered to be qualitatively transferred. In the quantitative experiment, first, we define a vector which consists of evaluation values for KANSEI words extracted in the quantitative experiments. We call it a sensitivity vector. Then, we measure the difference of the sensitivity vector between the object image and the reference image. We also measure the difference of the sensitivity vector between the original object image and the transferred image using the gradation feature of reference image. If these two differences have similar bias, we judge that impression or sensitivity is successfully transferred.

3.1. **Color transfer of image.** Figure 4(a) is an image of a Western carrot, and Figure 4(b) is an image of a Japanese carrot. Clipped areas are extracted from these images as shown in Figures 4(a) and 4(b). We performed color transfer experiment using these two images. We let Figure 4(a) be the reference image and Figure 4(b) be the object image. The image Figure 4(b) is transferred using the gradation feature of the image Figure 4(a). The result is shown in Figure 4(c). As we can see from these images, the impressions of the reference images are well transferred to the object images.

FIGURE 4. (a) Western carrot, (b) Japanese carrot, (c) Japanese carrot transferred

3.2. **Qualitative sensitivity evaluation.** KANSEI words were extracted from images in Figures 4(a), 4(b), 4(c) and other nine images by five experts such as graphic designers or digital creators. They were asked to write down their own impressions freely and these texts are analyzed by a text mining [10] procedure to produce KANSEI words. 8 to 14 KANSEI words were extracted for each image. These words are sorted in frequency order as shown in Table 1. In the table, (a), (b) and (c) are corresponding to the image of Figure 4(a), Figure 4(b) and Figure 4(c), respectively. We can see that the image of transferred Japanese carrot (c) has keywords of 'bright', 'Western carrot', 'ordinary' and 'like Hokkaido' (Hokkaido is a county in Japan which has large farmland). They are different from keywords of the image of Japanese carrot (b). From this result we can consider that impression of images changes by the color transfer.

3.3. **Quantitative evaluation of sensitivity.** Adjectives are selected based on the keywords obtained by text mining. And we executed sensitivity evaluation experiments by SD (Semantic Differential) method [11] to examine effect of color transfer. Using 12 adjective pairs in Table 2 as rating items, 55 examinees evaluated 12 images on a scale of 7 steps indicated by Table 3. Rating items are the adjectives obtained from text mining.

TABLE 1. Result of text mining for the images

(a) Western carrot

frequency	keywords
3	appetizing
2	fresh
1	reddish, bright, brilliant, not appetizing, seems hard, vigorous, healthy, natural, glaring, looks gentle, old, like animal feed

(b) Japanese carrot

frequency	keywords
2	sweet, like New Year's holiday, Japanese carrot, Japanese style
1	pale, appetizing, calm, old-fashioned, seasonable, fresh, like outdoor picture, like touch of soil

(c) Japanese carrot transferred

frequency	keywords
2	incongruous
1	bright, like Hokkaido, strong yellowish, like paintings, tricky, Western carrot, ordinary

TABLE 2. Rating items (adjective pairs)

1. not fresh	- fresh
2. not vigor	- vigorous
3. unappetizing	- appetizing
4. unhealthy	- healthy
5. artificial	- natural
6. Japanese-style	- Western-style
7. countrified	- elegant
8. restless	- calm
9. old-fashioned	- modern
10. sober	- showy
11. unstable	- stable
12. traditional	- innovative

TABLE 3. A part of the evaluation form

	extremely	quite	slightly	neither	slightly	quite	extremely	
	1	2	3	4	5	6	7	
1. not fresh	⊢	—┼—	—┼—	—┼—	—┼—	—┼—	—┤	fresh
	1	2	3	4	5	6	7	
2. not vigor	⊢	—┼—	—┼—	—┼—	—┼—	—┼—	—┤	vigorous

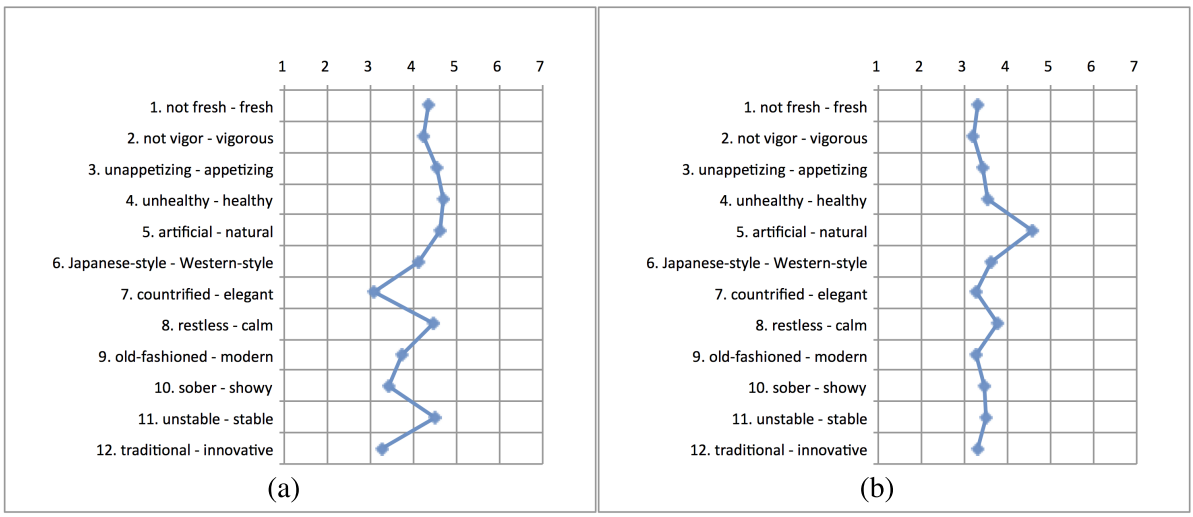

FIGURE 5. Rating scale average values for (a) Western carrot and (b) Japanese carrot

Figure 5(a) is the chart for average of evaluation value obtained from the image of Figure 4(a) 'Western carrot'. The rating items from 1 to 6 are evaluated as ranking 4 and over. Figure 5(b) is a chart for average of evaluation value obtained from the image of Figure 4(b) 'Japanese carrot'. The rating items from 1 to 4 and 6 are evaluated as ranking 4 and under.

As a result of evaluation (see Table 4), on the rating items 1, 2, 4 and 6, impressions of the image of Figure 4(b) 'Japanese carrot' change toward impression of its reference image (Figure 4(a) 'Western carrot'). We see that impression of the reference image is reflected on the transferred image by the proposed method, and the sensitivity of reference image is transcribed into the transferred object image.

TABLE 4. Evaluated values (average and standard deviation) obtained by SD method

		Adjective pairs					
		1	2	3	4	5	6
(a) Western carrot	Av.	4.35	4.24	4.55	4.69	4.62	4.13
	SD	1.38	1.50	1.40	1.44	1.48	1.39
(b) Japanese carrot	Av.	3.31	3.22	3.44	3.56	4.58	3.61
	SD	1.67	1.46	1.69	1.80	1.72	1.72
(c) Japanese carrot transferred	Av.	3.51	3.36	3.42	3.66	3.98	4.09
	SD	1.50	1.52	1.52	1.53	1.61	1.21

4. **Conclusions.** Recognizing the color distribution of an image as a gradation cluster, and quantifying the feature of gradation, we proposed a method to transfer the features of gradation in an image to another image. Change of image impression is qualitatively evaluated by text mining, and is quantitatively evaluated by SD method. From the result of the evaluation, we consider that the impression of an image is able to change to the impression of reference image by the color transfer.

In future, we will develop the tools for creating digital contents, such as color transferring systems using the database of gradation patterns related to sensitivity words. We expect that the users can easily transfer images by just choosing appropriate KANSEI words.

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