An Improved Method for Color Harmonization

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***Abstract*—Harmonic colors are color sets which have special internal relationships that are aesthetically pleasing to the human eye. Color harmonization is to find the best sets of colors which will make the image more comfortable to human visions. An improved technique of best scheme searching for automatic color harmonization is proposed in this paper. By considering the predominant color in image and its contribution to the harmonic image, this paper formulates a ratio method to find the best scheme. Moreover this paper suggests some change to the strategy of color shifting, thus makes the algorithm more efficient. In addition, this paper utilizes the conventional technique but produces better results through a set of simple processing. It is shown that the efficiency and accuracy of the new technique is significantly better than the traditional technique.**

Keywords-color harmonization;hue;graph-cut;color space

I. INTRODUCTION

Color harmony originated from the theory of white light spectrum which reveals relationship between physical nature and colors and is traced from Aristotle through Kandinsky, to Modern and Postmodern ideas. Systematic color harmony analyses were made by Newton, Goethe, and Chevreul, to name a few. Then came the round breaking color-vision research of Helmholtz and the notable scientific studies of Fechner and Rood. The color organization theories were brought forward by Munsell and Ostwald[1,2] and two kinds of quantitative representation for color harmony are presented according to their color systems. These works took the harmony in order. Art theorist Johannes Itten[3] proposed the theory of hue wheel with 26 different combinations of harmonic color relationships, his theory is popular among the artists and designers. Based on this theory, Matsuda[4] introduced a set of 80 color schemes by combining several types of hue and tone distributions used for harmony and design.

Color harmony is not only a very important researching field in human vision., since it can please one's eye and press a comfortable feeling, it can be also used in many businesses such as arts, interior design, video processing etc. Although color harmony using schemes thought to be lack of the relationship with context or culture, it still satisfies most people. There are many tools for color harmony, Meier et al.[5] presented a system for designing colors based on several color rules, and applied them to a graphical user inter-face (GUI) building tool, Daniel Cohen[6] proposed a new method which could automatically harmonizes a given color palette through an optimization process, and provides a means to automatically recolor an arbitrary image. Color harmony also gives some nudges in color transfer[7,10,11].

Our method is based on the work of Cohen, it can cope with the image with rich colors ,find the most suitable scheme automatically and keep some regions intact. The method proposed in this paper improved the optimization and recoloring method of Cohen's work. It takes the predominant hue of the image into account as well as a slight change in the recoloring function which minimizes the time cost.

II. HARMONIC SCHEMES

The harmonic schemes in this paper are brought forth by Matsuda[4].There are eight schemes in Figure 1, each scheme is defined on a hue wheel(the wheel composed of values in the hue channel). Hue wheel represents the different colors of the light spectrum in HSV color space in spite of the saturation and value. Hues distributed in the grey part thought to be harmonic. Each type is considered as a template, image colors coincide with any template are considered to be harmonic. However the templates can be rotated in arbitrary angles, then different harmonic hue combinations will appear. There are three kinds of templates, template consists of shades of the same colors (i,V,T), template composes of complementary color (Y,I,X) and template with other combination (L). Template N is a case of gray-scale images which is not our concerns.

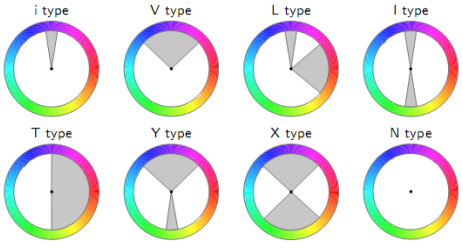


Figure 1. Schemes of harmonic colors

Financial support to this paper comes from The Teacher's Research Foundation of Hefei University of Technology (2008001), National Natural Science

Cohen[6] proposed an optimized method to choose a suitable template but the feature of image was neglected. Unlike that method, predominant hue of the image is taken into consideration.

In many cases, designers are reluctant to change the main feature of the image during the harmonic processing. We define a function to keep the main feature (in color) of the image:

$$F_h = n_h \bullet \bar{s}_h \quad (1)$$

n is the number of pixels in a particular hue, and $\bar{s}$ is the mean of the saturations of the pixels with that hue. If F is larger, the hue is probably the predominant one, otherwise it will be less valuable. Here we take the saturation into account because pixels with little saturation contribute less to the perception of image.

Each harmonic scheme can be defined by the template T_m and orientation angle α ,denoted by (m,α), $m \in \{i,V,L,I,T,Y,X\}$, $\alpha \in [0,2\pi)$. With this idea, we can define a function which used to find the best scheme:

$$F(X,(m,\alpha)) \quad (2)$$

$$F(X,(m,\alpha)) = \sum_{p \in X} \left\| H(p) - E_{T_m(\alpha)}(p) \right\| \bullet S(p)$$

Where X is the given image, p stands for any pixel in the image. $H(p)$ and $S(p)$ are the hue and saturation channel of pixel p. $E_{T_m(\alpha)}(p)$ is the hue of edge boundary of template m with orientation angle α which is closest to $H(p)$ .hue distance $\|\bullet\|$ refers to the arc-length distance on the hue wheel, and hues inside the sectors of T_m will have zero distance.

We want to find a template and an orientation angle to minimize function 2. That means the sector of template will include most significant pixels. The feature of image is used to fix orientation angle α. Predominant hue computed by function 1 can be used as the center hue of any sector in the template. Once the center of template sector is fixed the orientation angle is fixed, thus we only need to find the best template to minimize function 2.

Best harmonic scheme B(X) of a given image X is determined by minimizing the F function over all possible templates.

$$B(X) = (m_0, \alpha_0)$$

An Automatic method to find the best scheme is mentioned above, however users can choose their scheme manually if they want to get a different harmonic image (vary from the original one).

III. COLOR HARMONIZATION

Once the best scheme has been set, either automatically or manually, the harmony among the colors can be approached by shifting the color of X to the sectors of template. The hues outside will be shifted to the nearest sector of the best template according to the algorithm above, but the movement of the color is arbitrary, thus artifacts caused by "splitting" a contiguous region of the image will appear. Spatial coherency among the image pixels must be considered to solve such problem. We used the same strategy as Cohen[6] introduced in his work. Employing a graph-cut optimization technique[8]. The optimal label assignment

$$V = \{v(p_1), v(p_2) \cdots v(p_\Omega)\}$$

V is chosen to minimize the energy function E(V).

$$E(V) = \lambda E_1(V) + E_2(V)$$

E1(V) accounts for the distances between hues H(p) and H(v(p)) (the color of the assigned sector edge), and E2(V) indicates color coherence between neighboring pixels assigned to the same label.

$$E_1(V) = \sum_{i=1}^{|\Omega|} \left\| H(p_i) - H(v(p_i)) \right\| \bullet S(p_i)$$

$$E_2(V) = \sum_{\{p,q\} \in N} \delta(v(p), v(q)) \bullet S_{\max}(p,q) \bullet \left\| H(p) - H(q) \right\|^{-1}$$

N is the set of pixels in connected region, δ (v(p),v(q)) equals 1 if the labels v(p),v(q) are different, and 0 otherwise. S is the saturation.

Using this strategy may eliminate such artifacts, since spatial coherency is in our consideration.

IV. COLOR SHIFTING

All the pixels in image X will be associated to the best suitable sector using the graph-cut optimization technique. Then the recoloring of the image will be realized by shifting hues to the sector they should vest in. We use the formula below where we simplify Gaussian function[9] in Cohen's work[6]:

$$H'(p) = C(p) + \frac{w}{2}(1 - E_\sigma(\left\| H(p) - C(p) \right\|)) \quad (3)$$

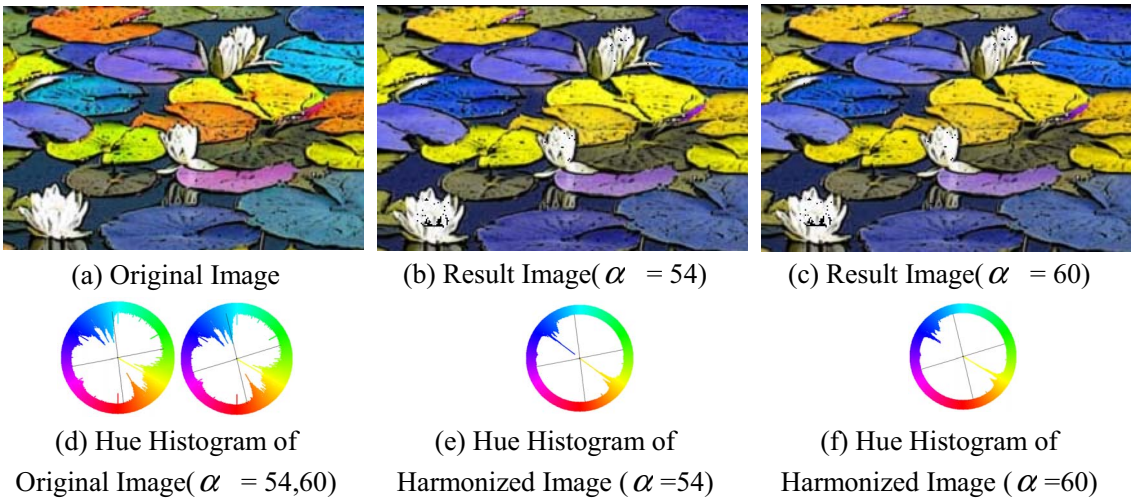
$$E_\sigma(t) = e^{-\frac{t^2}{2\sigma^2}} \quad (4)$$

C(p) is the center hue of the sector which pixel p associated with. w is the arc-length of this sector. σ equals to $\frac{w}{2}$ which found to be the best choice for color balance. E_σ is the function which value is between zero and one. Function 3 will enable hue monotonic (keeping hues in the right order). Function 4 will enable the center hue remain unchanged and contract hues into the sector.

V. RESULTS AND APPLICATIONS

Our improved color harmonization process can be used to harmonize all kinds of images and preserve the feature of original image. The original image and harmonized image are illustrated in Figure 2 by automatic methods: Cohen's and improved method. Table 1 shows the difference between Cohen's method and improved method. It compares the function value of different templates with the orientation angle calculated by Cohen's method and improved method. From the table the best orientation angle of Cohen's method is 54,however our method turned out to be 60. It's a slightly difference between them, thus have little impact on the result image (result images in Figure 2 can reveal it) However the time cost of our method is much smaller than Cohen's, our method is more efficient obviously. Figure 3 shows another example which harmonizes the background colors with respect to the

harmonic scheme of the foreground image. The image in the background harmonized according to the flags foreground.



(a) Original Image (b) Result Image(α = 54) (c) Result Image(α = 60)

(d) Hue Histogram of Original Image(α = 54,60) (e) Hue Histogram of Harmonized Image (α =54) (f) Hue Histogram of Harmonized Image (α =60)

Figure 2 Result Images and Hue Histograms by Cohen and Improved algorithm

TABLE I. COMPARE COHEN'S ALGORITHM WITH IMPROVED ALGORITHM

Cohen's method	**Template**	**i**	**V**	**L**	**I**	**T**	**Y**	**X**
	F-template	2224714	1072405	493496	422310	189772	220565	40446
	Orientation angle	54						
	Time cost	33984 ms						
Improved method	***Template***	i	V	L	I	T	Y	X
	F-template	2514050	1749780	564215	555936	247651	396070	46311
	Orientation angle	60						
	Time cost	79 ms						

Figure 3. Harmonized background image in respect to foreground

VI. CONCLUSIONS

An improved method for harmonizing colors is presented in this paper. This method can harmonize images automatically or manually. Comparing with previous method of color harmonization, our method is more efficient. Since the processing only alters the hues of

image, in future work we will take saturation and lightness channel into consideration.

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