Local Color Transfer via Color Classification

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Abstract

As an important image editing technique, color transfer plays an important role in image processing, which changes the original image color according to another image's color characteristics. This paper presents a new interactive local color transfer method. The user draws strokes specifying the target region needed to transfer colors, which can be segmented by an improved color classification method, and the new color will be transferred. The boundary of the result will be remedied by image matting. At the end of color transfer, only the color of the pixels in this segmented region is transferred, while others remain unchanged. The experimental results show that our method can achieve natural local color transfer results.

1. Introduction

With the increasing popularity of digital multimedia technology, intuitive digital image editing becomes more and more important in artistic designing or computational photograph, which mainly involves the global or local adjustment of the image's color, brightness, contrast, etc. Since general users are not professional photographers or designers, only the unsatisfied image region need image enhancement. However, it is not an easy task that directly making use of some image post-processing tools for image enhancement, by reason that such tools can only be used in global image editing. For example, the user is willing to change nothing but the color of flower in the image, but the color of green leaves in the background is transferred as well, which is clearly not what the user expects. Even if the foreground is subtly specified, this process is quite time-consuming, and results in artifacts near the boundary of the foreground and background. Therefore, it is very significant to segment out the region of interest(referred to ROI) for separated treatment.

Color transfer is a common image editing technology, widely used in movie production, photo processing, web design, etc. Consequently, color transfer of the user-specified image region has a very important realistic significance and application prospects. The interactive color transfer technique allows the changes of the original image color style based on user intent, which is more flexible than the automatic color transfer. In this paper, we focus on local color transfer. Based on the interactive technology, through color classification and image matting for image segmentation, the target image region is clear to employ color transfer.

The interactive local color transfer presented in this paper has three stages: user-specified target region segmentation, region boundary correction and color transfer. Users draw strokes in the original image and the reference image to specify the target region needed color transfer and the reference color. The pixels are classified using the K-means color classification with user specifies, which can roughly cut out the ROI. The boundary of that region is modified by a more precise image segmentation technology, image matting, using He's Guided Filter [1]. In the phase of color transfer, only the pixels in this region are applied color transfer, whereas others remaining unchanged, the result of which guarantees the maintain of original image details.

The contribution of this paper is to propose a new simple and effective interactive local color transfer method, providing a visual image color transfer mechanism for image enhancement.

The rest of this paper is organized as follows: The Section 2 summarizes the related work; The framework of our method is introduced in Section 3, describing the

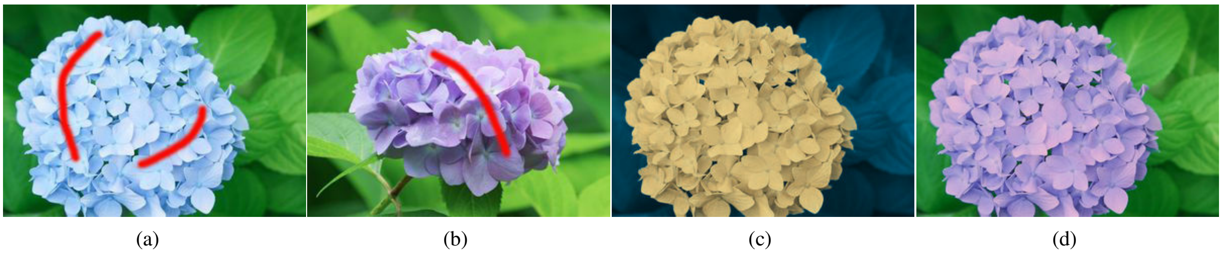

Figure 1: Overview of our approach: (a) source image with marked strokes; (b) reference image with the corresponding strokes; (c) the result of region extraction in pseudo colorization; (d) the final result.

details of the four stages of the method; Our experimental results are shown in Section 4, with some comparisons with the previous method. Finally, Section 5 concludes the paper and discuss our future work.

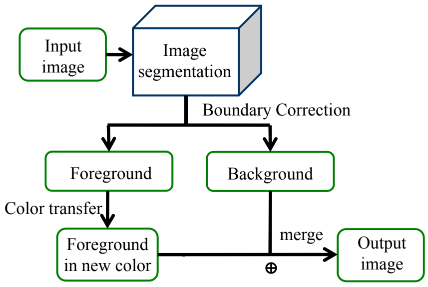

Figure 2: Local color transfer pipeline.

2. Related Work

In general, color transfer is classified into global color transfer and local color transfer. For different applications, they have respective advantages. Global color transfer conveys the whole color characteristics of a reference image to a source image. Ideally, the result is an updated source image which applies the color style of the reference image while preserving the scene of the original image.

Reinhard et al. [2] took lead in proposing a global color transfer method that imposes a reference image's color characteristics onto another source image using statistical analysis. By computing the mean and variance of the pixel color, the pixel color is transferred, which naturally keeps the image content. Effective as it is, the quality of color transfer relies on the source and reference images' similarity in composition. In [3], Pitie et al. presented an improved histogram-matching method using an N-dimensional probability distribution function (PDF) transfer algorithm, globally transfers colors between images. Obviously, this method is able to maintain the color distribution of the image. Xiao et al. [4] cast the problem into a nonlinear optimization problem, constructing the color transferred image by combining the reference image's color histogram and the source image's gradient map, solving the fidelity problem of Reinhard's method [2]. In [5], Pouli et al. applies histogram matching into the image decomposition. This approach allows color transfer between high dynamic images and low dynamic image. However this method is hard to satisfy users' requirements of transferring varieties of colors.

In addition, under classification framework, a variety of methods are proposed using the color mapping in [2] to achieve a better color transfer results, e.g. Chang et al.'s basic color categories based method [6], Tai et al.'s probabilistic segmentation color transfer [7], Wang et al.'s data-driven image color theme enhancement [8], Dong et al.'s dominant colors mapping based method [9] and Wang et al.'s training based method [10].

There have been proposed many algorithms for local color transfer. Image segmentation is a simple and feasible solution for local color transfer. Wen et al. [11] proposed a image enhancement system by using interactive color transfer algorithm. According to the user strokes, an improved graph cut algorithm was a for applied segmentation at first, and a Gaussian probability-weighted color transfer algorithm was applied between corresponding image area pairs. At the end, the authors used a gradient based smoothness term to improve the results, which improve the controllability of the method.

Another important color transfer method is the propagation of new color to the whole image [12] [13] [14]. Colorization problem is a special color transfer problem. Based on the assumption that adjacent pixels having similar values should have similar colors. Levin et al. proposed a colorization method [13], based on user strokes, constructing a quadratic optimization equation, to impart color to the image. Lischinski et al. proposed interactive local tone adjustment method based on sparse strokes [14]. By marking, the image is divided into several regions, so that parameters can be partially adjusted, such as brightness.

Editing propagation is an important local color transfer theory. Wang et al. [15] presented the mean value coordinates based local color transfer method. Applying Reinhard's linear color transfer method [2] and the discrete mean value coordinates model, the new colors were propagated to the whole image. Li et al. [16] casted the editing interpolation to the radial basis function interpolation, improve the efficiency of color transfer for large image and video.

3. Color Classification based Local Color Transfer

Firstly, we briefly present the framework of our method as shown in Fig.2. The local color transfer method we proposed exploits color classification, image segmentation, image matting, and color transfer technology. As premises, user should draw several strokes on the source image and the reference image, to specify the color need to be transferred and new color. At the second stage, we apply an improved color classification method to segment out the expected region, the boundary of which is corrected by matting in the following stage. Finally, a local color transfer operation is applied to transfer the color from the reference image to the source image.

3.1 User Stroke

What are necessary for color transfer are the original color from the original image and the new color from the reference image. It is easy to get these colors by drawing strokes on images. Specially, those strokes on the source image ought to involve all the colors that need to transfer in the target region, to ensure accuracy color classification.

The pixels of source image can be denote as $\langle p, v, C, R \rangle$, p presents the coordinates of the pixel, v is the color vector, C is the color classifications, and R labels whether the pixel is in the target region. Given a source image I_s and a reference image I_r, we denote the final color transfer result as I_t. $P_s = \{(p_i, v_i, C_i, 1)|i = 1, ..., n\}$ and $Q_r = \{(p_j, v_j)|j = 1, ..., m\}$ respectively present the set of pixels under the user strokes in the source image and the reference image. Generally, $P_s \in I_s$.

3.2 Region Extraction by Color Classification

It is necessary to first segment the ROI out for local color transfers. We first use K-means algorithm to divide the colors into different regions. According to the original colors from user strokes, we merge corresponding regions to get a rough target region. The procedure of this region extraction method is shown in Fig.3.

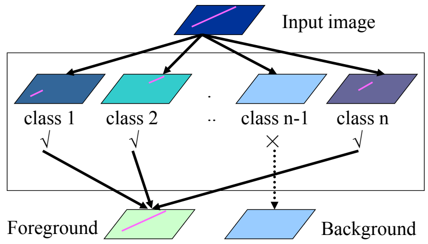

Figure 3: Region extraction via color classification. The ROI and the amount of color are specified by user stroke and assignment.

We first convert the image to Lab color space, and apply K-means algorithm to the whole image to classify all the pixels. Select K centroids, denote as $z_1(1)$,$z_2(1)$, ,$z_K(1)$. In every iteration, we calculate the distance $dis(x, z_l(1))$ between pixel x and the centroid $z_l(1)$, $l = 1, 2, ..., K$. Here, the distance $dis(i, j)$ is defined as follows

$$dis(i,j) = a\sqrt{(l_i - l_j)^2 + (\alpha_i - \alpha_j)^2 + (\beta_i - \beta_j)^2}. \tag{1}$$

At the end of classification, every pixel's color classification is determined. If pixel i and pixel j belong to the same classification, $j \in P_s$, $R_i = 1$, otherwise $R_i = 0$. Through this process, we can segment out a rough target region which has the same colors with the user stroke.

3.3 Boundary Correction

Classification based on color can only get a relatively rough segmentation results, if the original image has varieties of colors. These results generally arouse residuals near the edge, which has significant influence on the following color transfer. Image matting is widely used in image synthesis and film special effects production, to elaborately separate the foreground and background of the image. Applying image matting, we can remedy the boundary of target region. Guided Filter proposed by He et al. [1], has various of applications, such as noise reduction, detail smoothing/enhancement, HDR compression, Matting, etc., which performs very well at edge-preserving smoothing, and will not cause edge residual. Therefore, we introduce Guided Filter into our method for boundary correction.

The Guided Filter assumes that it is local linear between guidance I and the output q, $q_i = a_k I_i + b_k, \forall i \in \omega_k$. a_i,b_i are some linear coefficients. We assume that q is a linear transform of I in a window ω_k centered at the pixel k.

We can minimize the difference between q and input p to determine the linear coefficients through minimizing the following cost function [1]

$$E(a_k, b_k) = \sum_{i \in \omega_k} ((a_k I_i + b_k - p_i)^2 + \varepsilon {a_k}^2), \quad (2)$$

where ε is a regularization parameter. According to linear regression, we can get the solution of the cost function [1]

$$a_k = \frac{\frac{1}{|\omega|}\sum_{i \in \omega_k} I_i p_i - \mu_k \bar{p}_k}{\sigma_k^2 + \varepsilon}, b_k = \bar{p}_k - a_k \mu_k. \quad (3)$$

μ_k and σ_k^2 are mean and variance of I in ω_k. $|\omega|$ is the number of pixels in $\omega_k \bar{p}_k = \frac{1}{|\omega|}\sum_{i \in \omega_k} p_i$ is the mean of p in ω_k. Therefore, we can calculate the output [1]

$$q_i = \frac{1}{|\omega|} \sum_{k: i \in \omega_k} (a_k I_i + b_k). \quad (4)$$

The results of color classification is binary input p, and the source image is the guidance I, according to the above formula, we can compute an accurate matte, and adaptively adjust it to get a binary target region with clear boundary.

3.4 Color Transfer Operator

We apply the method proposed by Reinhard et al. [2] to transfer the color of the target region. Define the mean and variance of the target region ${I_s}'$ and the set of pixels of the reference image Q_r as follows

$$\mu_s = \frac{1}{n'}\sum_{i=1}^{n'} v_i, \sigma_s = \frac{1}{n'}\sum_{i=1}^{n'} (v_i - \mu_s)^2;$$

$$\mu_r = \frac{1}{m}\sum_{j=1}^{m} v_j, \sigma_r = \frac{1}{m}\sum_{j=1}^{m} (v_j - \mu_r)^2.$$

According to the formula provided in the Reinhard's method, we can calculate the new color of pixels ${I_s}' = \{(p_i, v_i, C_i, 1) | i = 1, ..., n'\}$ by

$$\bar{v}_i = \frac{\sigma_r}{\sigma_s}(v_i - \mu_s) + \mu_r. \quad (5)$$

Consequently, we get the final result $I_t = \{(p_i, \bar{v}_i, C_i, 1) | i = 1, ..., n'\} \cup \{(p_j, v_j, C_j, 0) | j = 1, ..., N - n'\}$.

4. Experiment Results and Discussion

In this section we present our experimental results and the comparisons with previous methods. The experimental input is a source image and a reference image with the user strokes on corresponding image region using the same color brush. Note that it is unnecessary to mark the unchanged region of source image, which on contrary is essential for previous methods. Our approach can be easily extended to the case of multiple strokes or multiple reference images.

Most of the experiment with parameters K=5 and the radius of window in matting r=60 achieve good results. We first compare the results of Wang's method [15]. It's hard to tell the difference between the results in the first row of Fig.4, however discoloration can be observed in the result by scattered point interpolation approach as shown in Fig.4 (c)(see the top-left of the balloon and the middle second-floor wooden window), on account of the amount of the subset of user-selected pixels instead of all pixels to perform propagation. On the other hand, our results showed in Fig.4 (d) are more natural. It also explains the proportion of user-selected pixels is very important in the case that it is insufficient for propagation.

Fig.5 shows the two comparisons of our method and the edit propagation approach proposed by Li et al. [16]. The background in images of the first row of Fig.5 (c) has been changed greatly. In second row of Fig. 5, only one kind of strokes is given where the specified pixels' color will change into the new color, while in the experiment of first row is given both strokes that specify the color of pixels to be transferred and the ones remain unchanged. Because the pixels' color is dissimilar to those in the strokes, the new color tends to be zero, see the grass in the bottom image in Fig.5 (c).

Our approach is weak in dealing with similar colors, in resulting inaccurate color classification in color classification, which can lead to incorrect color near the boundary of target region in color transfer as shown in Fig.6.

5. Conclusion

In this paper, we propose a new local color transfer exploiting color classification and linear color transfer. We particularly apply image matting for segmentation, so that the boundary of target region is sufficient precise for the following stage, color transfer. Our experiments show that our method can segment the target region out to transfer colors, according to the users' expectations. Finally, Our method need to make a further improvement on the discrimination of similar colors.

Acknowledgments

This research is supported by NSFC-Guangdong Joint Fund (U0935004, U1135003), the National Key Technology R&D Program (2011BAH27B01, 2001BHA16B08), the Major Science and Technology Projects of Guangdong (2011A080401007),

(a) (b) (c) (d)

Figure 4: Comparisons with Wang's method: (a) source image; (b) reference image; (c) result of Wang's method in [15]; (d) result of our method with $n = 5$ (first and second rows) and $n = 6$ (bottom row).

the Industry-academy-research Project of Guangdong (2009A090100028, 2011A091000032), and the Industry-academy-research Project of Science and Information Technology Bureau of Panyu Guangdong (2010-Zhuan-12-09). Thank all the authors providing images for our experiment, as well as adamnsinger.

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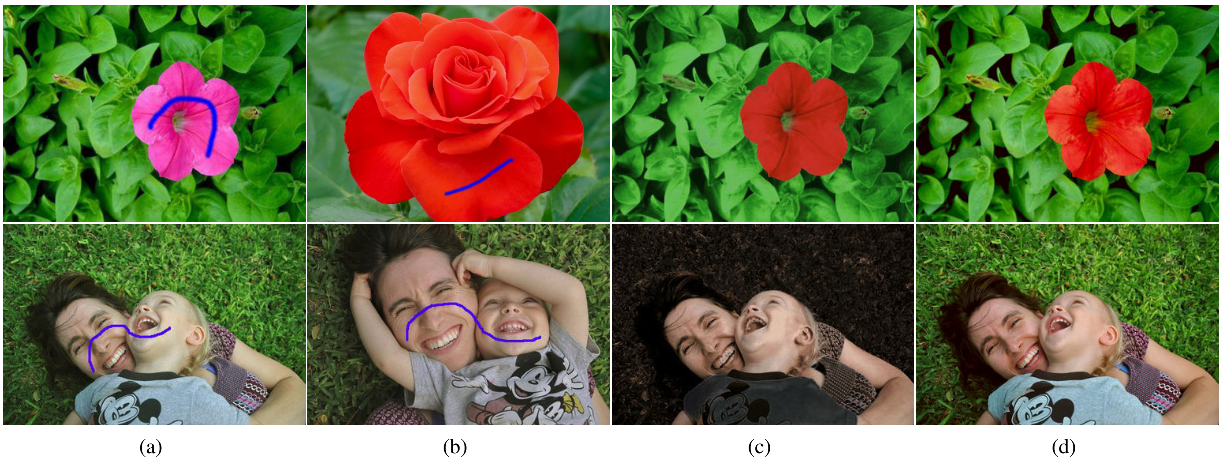

Figure 5: Comparisons with Li's method: (a)source image; (b) reference image; (c) result of Li's method in [16] with $\sigma_c = \sqrt{0.2} = 0.4472$; (d) result of our method with $n = 5$ (both rows).

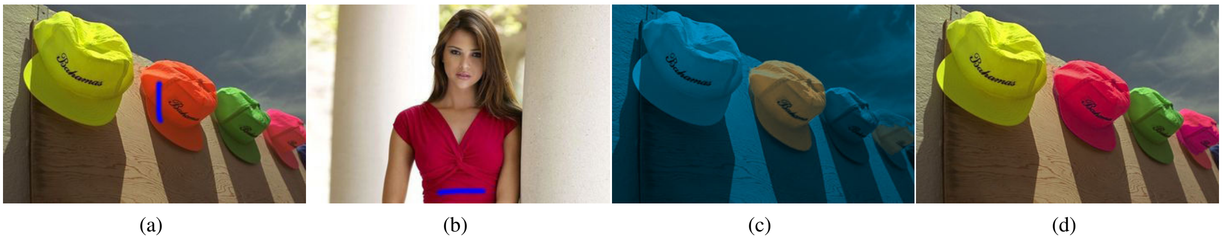

Figure 6: Undesirable result: (a) source image; (b) reference image; (c) result of region extraction; (d) result of our method with $n = 10$.

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