Color Transfer Based on Multiscale Gradient-aware Decomposition and Color Distribution Mapping

Zhuo Su, Daiguo Deng, Xue Yang, Xiaonan Luo
National Engineering Research Center of Digital Life, State-Provence Joint Laboratory of Digital Home Interactive Applications, School of Information Science & Technology, Sun Yat-sen University
Shenzhen Digital Home Key Technology Engineering Laboratory, Shenzhen Key Laboratory of Digital Living Network and Content Service, Research Institute of Sun Yat-sen University in Shenzhen
suzhuoi@gmail.com, lnslxn@mail.sysu.edu.cn

ABSTRACT
Automatic global color transfer is a challenging problem in image editing. In this paper, we propose a novel color transfer method, which is based on the gradient-aware decomposition and the color distribution mapping. Firstly, a gradient-aware decomposition model is established to separate the target image into the base and detail layers. Then, the colors of each separated base layer are enforced to match those of a given reference image by Pitié’s multi-dimensional probability density function transfer method. After that, all mapped base layers are combined with corresponding boosted detail layers to produce the final output. The experiments demonstrate that our method can achieve a visual satisfied result without post-processing gradient correction.

Categories and Subject Descriptors
I.4.3 [Image Processing and Computer Vision]: Enhancement—Filtering

General Terms
Algorithms, Experimentation

Keywords
color transfer, distribution, gradient-aware decomposition

1. INTRODUCTION
Color performance can reflect the style of an image. In the field of photography, rich colors are used to perform artistic style and visual effect. For art design, we apply color editing to get some specific art effects. However, it is difficult to obtain a visual satisfied editing result, usually needing complicated color matching model. Therefore, how to edit colors effectively and efficiently becomes a challenging problem. The state-of-the-art color transfer methods are introducing some user-specified reference images. With establishing the color mapping relationship between the target image and the reference image, the referenced colors are transferred to make the target close to the reference in color performance. Linear color mapping between the target image and the reference image is an intuitive way. However, due to the complicated color variation, these methods produce serious visual artifacts, e.g., grain effect, color distortion.

In this paper, we propose a new color transfer method, which is based on the gradient-aware decomposition and the color distribution mapping, to realize the visual satisfied color transfer. Firstly, we establish a gradient-aware decomposition model and use this model to implement multiscale image decomposition. Then, a color mapping method proposed by Pitié et al. [6] is applied to the decomposition results to construct the mapping relationship between target image and reference image. After the mapping, the final result is produced through the multi-level composition which combines the boosted details with the mapped base layers. Fig. 1 shows the pipeline of our method.

The contributions of this paper are as follows. 1. Establish a gradient-aware image decomposition model based on the variational optimization. 2. Improve Pitié’s color distribution mapping model without post-processing gradient correction. 3. Propose a grain-free and detail boosting scheme for the color transfer problem.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. MM’12, October 29–November 2, 2012, Nara, Japan.
Copyright 2012 ACM 978-1-4503-1089-5/12/10 ...$15.00.

Figure 1: The pipeline of our method.

2. RELATED WORK
Our paper refers to edge-preserving decomposition and color mapping approach, and we will summarize the state-of-the-art methods in the following.

Edge-Preserving Decomposition. The linear filter can separate out the low- and high-frequency signals from an image, but it would produce halo artifacts along the edges. These artifacts can be reduced by the edge-preserving smoothing (EPS) filters. The state-of-the-art EPS filters are represented by the bilateral filter (BLF) [5] and the optimization-
basically overcome the problem caused by the BLF. We decompose. Here, we propose a gradient-aware decom-

3. GRADIENT-AWARE DECOMPOSITION

Bae et al. [2] introduced a two-scale color transfer method using BLF to decompose the image and demonstrate the feasibility of edge-preserving decomposition on color transfer problem. However, Poisson correction [2] is indispensable to prevent potential gradient reversal brought by the bilateral decomposition. Here, we propose a gradient-aware decomposition method based on optimization framework which can essentially overcome the problem caused by the BLF. We define the optimized energy equation in the following

where $H(\cdot)$ is the gradient-aware function used to reflect and control image gradient magnitude. $\nabla$ is a gradient operator; $\delta$ is a gradient control parameter, which can enhance or restrain the gradients; $\varepsilon$ is a small constant of error-correction. The discrete form of $H(\cdot)$ is defined in the following

Gradient-aware image decomposition is to minimize the energy in Eq. 1, where $\lambda$ is a regularization factor, used to balance the data term $E_d$ and smooth term $E_g$ and control the smoothness. Actually, our method is an extension of Total Variation (TV) model. Fig. 3 compares some mentioned edge-preserving decomposition methods with our method. With the smoothness increasing, BLF [5] was likely to blur some edges or produce the halo in Fig. 3(c). WLS filter [4] smoothed most of noises while keeping the edges sharp but some block-like artifacts appeared in Fig. 3(d). L0GM [13] and our method smoothed the noises while keeping the edges sharp and the regions flat in Fig. 3(e) and (f). However, we will demonstrate our method more suitable for image decomposition in the following.

4. COLOR DISTRIBUTION MAPPING

According to the probability distribution function theory, color distribution mapping is a matching problem between the random variables of the target image and the variables of the reference image. Let $f$ and $r$ denote the color variables, the mapping relationship is defined in the following

In the histogram matching, mapping function can be defined as $T(r) = \int_0^r p_t(w)dw$ and $G(f) = \int_0^f p_f(s)ds$, where
Grain effect and image detail preserving are two important problems in color transfer. If the color does not match well, it will produce grain effect and loss image detail. Pitié et al.’s PDF matching method [6], Xiao et al.’s gradient-preserving method [12], and Dong et al.’s dominant color-based method [3] adopted the gradient-preserving strategy to prevent the grain effect and preserve the details. Our method takes advantage of edge-preserving decomposition to construct the base-detail pair \((S^i, D^i)\). Through controlling base-detail pair of the target image, we can prevent the grain effect while enhancing the details in the color transferred image. These base-detail image pairs can be obtained in the following: \(D^i = f - S^i\).

The base images from decomposition is used to color transfer. Since the base image has the property of smoothness, color transition performs local smoothness which can avoid the grain effect effectively. In addition, considering the detail boosting, the boosted image \(\tilde{f}\) can be constructed in the following ways

\[
\tilde{f} = \log_{10} \left[ \sum_{i=1}^{k} \alpha^i S^i + \kappa \sum_{i=1}^{k} \left(1 - \alpha^i\right) D^i \right],
\]

where \(\alpha\) is the weighted factor to balance each base-detail pair in the combination. The parameter setting for each pair can be evaluated by Gaussian normal distribution function. \(\kappa\) is the enhanced factor for the detail boosting. As illustrated in Fig. 5, the grain effects are prevented in Fig. 5(c), and the details are boosted in Fig. 5(d). Comparing the before and after results, we found that the detail performance in Fig. 5(f) is better than that in Fig. 5(e).

6. RESULTS

In this section, we compare our method with the state-of-the-art methods in visual performance. All the experiments are tested on PC with Intel 15-2450M 2.5GHz CPU, NVIDIA 610M, 4GB DDR3 Ram, and MATLAB R2010a. Empirically, we decompose the target image into the coarse, medium and fine scale in base-detail pair. And we set the iteration \(n=20\) for the color mapping in Eq. 5.

In Fig. 2(c), it is obvious that the small river appears dark green with serious grain effect and overall color distortion. Although the color distortion dose not appear in Fig. 2(d), the result is not visual satisfied. Note that in Fig. 2(d), the transferred colors are out of the color range of the reference image causing the unexpected distortion, especially in the leaves and the stones. In Fig. 2(e), Xiao’s method produces an unsatisfied mapping in leaves as well. Without the gradient-preserving correction, our result (\(\alpha=1.2, \lambda=[8.0, 1.0, 0.125]\)) shows a satisfied look in Fig. 2(f) as well.

More comparisons are shown in the Fig. 6. In the top row, serious color distortions appear in Fig. 6(e) and Fig. 6(d). However, Fig. 6(e) and Fig. 6(f) (\(\lambda=1, t=50\)) appear in the visual satisfied color performance.

In the middle row, serious grain effect appears in the Fig. 6(e), which demonstrates that the direct histogram matching is not suitable to the scene with major difference between the target and the reference. In both Fig. 6(d) and Fig. 6(e), the style of both the sky and the boat is the same with that in the target image, but different from the expected style of the reference image. The reason that the number of dominant colors in the target is less than that in the ref-
The result of our method ($\lambda=1$, $t=50$) is shown in Fig. 6(f). With the multi-dimensional histogram mapping, the artistic style of the result is close to the reference image and obtains a visual satisfied performance. Especially, adopting gradient-aware decomposition model, our method is more suitable than the mentioned methods in detail boosting. Note that in Fig. 6(f), the tower has a sound detail performance while those of both Fig. 6(d) and Fig. 6(e) have the obscure shape merely.

In the bottom row of Fig. 6, obvious color distortion is illustrated in Fig. 6(c). Although Dong’s and Wu’s methods transfer all colors of the reference image, the geometric distribution of the colors in the target image has been changed in Fig. 6(d) and Fig. 6(e). Our method ($\lambda=1$, $t=50$) transfers well with preserving the color distribution of the target image as shown in Fig. 6(f).

7. DISCUSSION AND FUTURE WORK

In this paper, we propose a novel color transfer method based on multiscale gradient-aware decomposition and color distribution mapping. We decompose the target image into base-detail pairs appropriately using our gradient-aware operation and manipulate them separately. Our method can not only produce a grain-free color mapping, but also balance the color performance and the details in a visual satisfied way. However, some disadvantages still exist in current implements. When the target image contains many areas with similar colors, our method is likely to map these areas to the same colors, and to cause some block-like artifacts and the local color contrast distortion. In addition, the iterations in the color distribution mapping would slow down the computational efficiency. We will try to improve the above defects in our future work.

Acknowledgements

This research is supported by the NSFC-Guangdong Joint Fund (U0935004, U1135006), the National Key Technology R&D Program (2011BAH27B01, 2011BHA16B08), the Industry-academy-research Project of Guangdong (2011A091000032), and the National Natural Science Foundation of China (61100080).

8. REFERENCES