

# Scene Relighting using a Single Reference Image through Material Constrained Layer Decomposition

Xin Jin<sup>1</sup>, Yannan Li<sup>1</sup>, Ningning Liu<sup>2</sup>, Xiaodong Li<sup>1,\*</sup>,  
Quan Zhou<sup>3,4</sup>, Yulu Tian<sup>1</sup>, Shiming Ge<sup>5,\*</sup>

<sup>1</sup>Beijing Electronic Science and Technology Institute, Beijing, 100070, P.R. China

<sup>2</sup>University of International Business and Economics, Beijing, 100029, P.R. China

<sup>3</sup>National Engineering Research Center of Communications and Networking,  
Nanjing University of Posts and Telecommunications, P.R. China

<sup>4</sup>State Key Lab. for Novel Software Technology, Nanjing University, P.R. China

<sup>5</sup>Institute of Info. Engineering, Chinese Academy of Sciences, Beijing, 100093, P.R. China

\*Corresponding authors: [lxid@besti.edu.cn](mailto:lxid@besti.edu.cn), [geshiming@iie.ac.cn](mailto:geshiming@iie.ac.cn)

**Abstract:** Image relighting is to change the illumination of an image to a target illumination effect without known the original scene geometry, material information and illumination condition. We propose a novel outdoor scene relighting method, which needs only a single reference image and is based on material constrained layer decomposition. Firstly, the material map is extracted from the input image. Then, the reference image is warped to the input image through patch match based image warping. Lastly, the input image is relighted using material constrained layer decomposition. The experimental results reveal that our method can produce similar illumination effect as that of the reference image on the input image using only a single reference image.

**Keywords:** Image Relighting, Single Reference Image, Material Map, Layer Decomposition

## 1 Introduction

Image relighting is a hot topic in the communities of computer vision, image processing and computational photography. The applications of image relighting include visual communication, film production and digital entertainment, etc.

Image relighting is to change the illumination of an image to a target illumination effect without known the original scene geometry, material information and illumination condition. Comparing with face, object and indoor scene, two main challenges are for outdoor scene relighting: (1) large scale outdoor scene with multiple objects, which are not easy to reconstruct; (2) complex illumination in outdoor scene, which is hard to be controlled manually. Recently, reference image based image relighting has shown great potential [1][2][3][6]. Currently, for face relighting, the reference images are changed from multiple and a pair [4] to a single [3]. For object relighting [2][9] and scene relighting [1], multiple or a pair reference images are still needed [10][11][12][13][18].

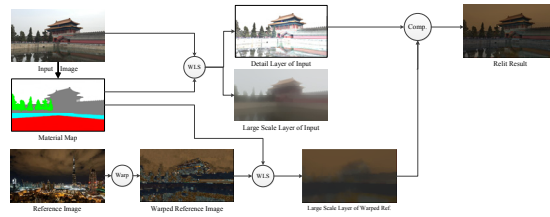
We propose a novel outdoor scene relighting method, which needs only a single reference image and is based on material constrained layer decomposition. Firstly, the material map is extracted from the input image. Then, the reference image is warped to the input image through patch match based image warping. Lastly, the input image is relighted using material constrained layer decomposition. The experimental results reveal that our method can produce similar illumination effect as that of the reference image on the input image using only a single reference image.

## 2 Scene Relighting

### 2.1 Method Overview

Our proposed method can be divided into 4 steps, as shown in Fig. 1: (1) the input image is segmented to the material map using the method of Bell et al. [16]. Every pixel of the material map is assigned by a material label; (2) the reference image is

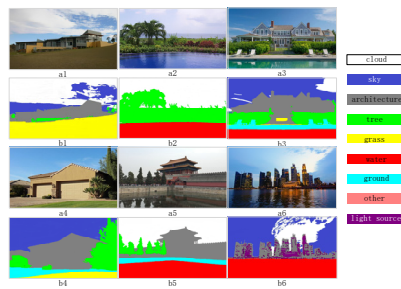
warped to the structure of the input image by the patch match warping; (3) each channel of the input image and the reference is decomposed to large scale layer and detail layer under material constrain; (4) the final relit results are obtained by composing the details of the input image and the large scale of the warped reference image.



**Fig. 1.** Scene relighting using only a single reference image.

## 2.2 Material Segmentation

The input image is segmented according to the material of each pixel. We use the method of Bell et al. [16] to obtain material label of each pixel. We make the material segmentation because that in different material region, different relighting operations should be conducted. We select 9 sorts of materials, which often appear in outdoor scene images, as shown in **Fig. 2**. We recolor each pixel according to the material label to get the material map. The first and the third lines are the input images. The second and the fourth lines are the corresponding material maps.



**Fig. 2.** The material maps of the input images

### 2.3 Reference Image Warping

In face image relighting, the reference face image can be warped by face landmark detection / face alignment. However, in outdoor scene, we cannot find such similar structure easily. The outdoor scene contains multiple objects. Thus, we use the patch match method to warp the reference image to the input image, i.e. to align the reference and the input image. The patch match algorithm is similar as the method of Barnes et al. [14]. We use the neighbor patches whose best matched patches have already been found to improve matching result of current patch. The difference from Barnes et al. [14] is that we use 4 neighbor patches instead of 3 ones.

### 2.4 Layer Decomposition and Composition

We use the WLS filter [15] to decompose image into large scale layer and detail layer, which can be considered as the illumination component and non-illumination component. Using the large scale layer of the warped reference to substitute the large scale layer of the input can produce the final relit result. The outdoor scene contains various objects with various materials. Thus for different material, different decomposition parameters should be used. Each channel  $l$  of the input image and the reference image is filtered to a large scale layer  $s$ . The detail layer  $d$  is obtained by:  $d = l/s$ .

The original WLS filter uses the same smoothness level over the whole image. When using the WLS filter for our scene relighting task, we need make regions with different materials with different smooth levels. Thus, we set different smoothness levels in regions with different materials. We modified the original WLS [15] as:

$$E = |l - s|^2 + H(\nabla_s, \nabla l) \quad (1)$$

$$H(\nabla_s, \nabla l) = \sum_p \left( \lambda(p) \left( \frac{(\partial s / \partial x)_p^2}{(\partial l / \partial x)_p^{\alpha + \varepsilon}} + \frac{(\partial s / \partial y)_p^2}{(\partial l / \partial y)_p^{\alpha + \varepsilon}} \right) \right), \quad (2)$$

where,  $|l - s|^2$  is the data term, which is to let  $l$  and  $s$  as similar as possible, i.e., to minimize the distance between  $l$  and  $s$ .  $H(\nabla_s, \nabla l)$  is the regularization (smoothness) term, which makes  $s$  as smooth as possible, i.e. to minimize the partial derivative of  $s$ .  $p$  is the pixel of the image.  $\alpha$  controls over the affinities by non-linearly scaling the gradients. Increasing  $\alpha$  will result in sharper preserved edges.  $\lambda$  is the balance factor between the data term and the smoothness term. Increasing  $\lambda$  will produce smoother images.  $\varepsilon$  is a very small number, so as to avoid the division by 0. Our  $\lambda$  is the smoothness level constrained by different materials, using the material map derived in Section 3.2:

$$\lambda = \nabla 1 + \text{gray}(l_m)/255, \quad (3)$$

where,  $\nabla 1$  is the gradient of  $l$ .  $l_m$  is the material map of  $l$ , and the gray is the gray value of  $l_m$ :

$$\text{gray} = (R * 0.2989 + G * 0.587 + B * 0.114). \quad (4)$$

The minimization of Eq. (1) and Eq. (2) can be solved by the off-the-shell methods such as Lischinski [17]. At last, using the large scale layer of the warped reference to substitute the large scale layer of the input can produce the final relit result.

### 3 Experimental Results

In this section, we show the experimental results of our proposed method and the comparison with the state of the art method.

#### 3.1 The Scene Relit Results

The relit results of our method are shown in Fig. 3. (a): multiple input images, (b): the same reference image, (c): warped reference image, (d): relit results of input images using (c). The experimental results reveal that, the relit input image have similar illumination effect as that of the reference image.



**Fig. 3.** The relit results of our method

### 3.2 Comparison with Other Methods

We compare our method with the state of the art method [1], which needs a time-lapse video captured by a fixed camera working for 24 hours. While our method needs only a single reference image. We randomly select 5 input images for comparison. As shown in Fig. 4, (a): multiple input images, (b) the reference image, (c): warped reference images to corresponding input images, (d): warped reference images using method of [1], note that they need a time-lapse video for warping, (e): the relit results using our proposed method, (f): the relit results using the method of [1]. The results reveal that our method can produce similar relit results as those of [1], with only a single reference image.



**Fig. 4.** Comparison with [1]

## 4 Conclusion

We propose a novel outdoor scene relighting method, which needs only a single reference image and is based on material constrained layer decomposition. The experimental results reveal that our method can produce similar illumination effect as that of the reference image on the input image using only a single reference image.

## Acknowledgements

We thank all the reviewers and PCs. This work is partially supported by the National Natural Science Foundation of China (Grant NO.61402021, 61401228, 61640216), the Science and Technology Project of the State Archives Administrator (Grant NO. 2015-B-10), the open funding project of State Key Laboratory of Virtual Reality Technology and Systems, Beihang University (Grant NO. BUAA-VR-16KF-09), the Fundamental Research Funds for the Central Universities (Grant NO.2016LG03, 2016LG04), the China Postdoctoral Science Foundation (Grant NO.2015M581841), and the Postdoctoral Science Foundation of Jiangsu Province (Grant NO.1501019A).

## Reference

- [1] Yichang Shih, Sylvain Paris, Frédo Durand, and William T. Freeman.: Data-driven hallucination of different times of day from a single outdoor photo. *ACM Trans. Graph.* 32, 6, 11 pages Article 200 (2013).
- [2] Haber T, Fuchs C, Bekaer P, et al.: Relighting objects from image collections. *Computer Vision and Pattern Recognition, 2009. CVPR 2009. IEEE Conference on. IEEE, 2009: 627-634 (2009).*
- [3] Xiaowu Chen, Hongyu Wu, Xin Jin and Qinpeng Zhao.: Face Illumination Manipulation using a Single Reference Image by Adaptive Layer Decomposition. *IEEE Transactions on Image Processing (TIP)*, Vol. 22, No. 11, pp. 4249 – 4259 (2013).
- [4] Jiansheng Chen, Guangda Su, Jinping He, Shenglan Ben.: Face Image Relighting using Locally Constrained Global Optimization. *Computer Vision – ECCV 2010 Volume 6314 of*

the series Lecture Notes in Computer Science pp 44-57 (2010).

- [5] Y. Wang, Z. Liu, G. Hua, Z. Wen, Z. Zhang, and D. Samaras.: Face re-lighting from a single image under harsh lighting conditions. In Proc. CVPR (2007).
- [6] Pieter Peers, Naoki Tamura, Wojciech Matusik, and Paul Debevec.: Post-production Facial Performance Relighting using Reflectance Transfer [J]. ACM Transactions on Graphics, August 2007, Volume 26, Issue 3, Article 52 (2007)
- [7] Eisemann, E., And Durand, F.: Flash photography enhancement via intrinsic relighting [J]. ACM Trans. Graph., 2004, 23, 3(August), 673-678 (2004)
- [8] AGRAWAL, A., AND RASKAR, R. 2007.: Gradient domain manipulation techniques in vision and graphics [Z]. In ICCV 2007 Courses (2007)
- [9] Xin Jin, Yulu Tian, Chaochen Ye, Jingying Chi, Xiaodong Li, Geng Zhao.: Object Image Relighting through Patch Match Warping and Color Transfer. The 16th International Conference on Virtual Reality and Visualization (ICVRV), Hangzhou, China, 23-25 September, pp.235-241 (2016)
- [10] H. Lu, J. Guna, D. G. Dansereau, Introduction to the special section on Artificial Intelligence and Computer Vision, Computers & Electrical Engineering. Vol. 58, pp. 444-446, 2017
- [11] H. Lu, Y. Li, S. Nakashima, H. Kim and S. Serikawa, Underwater Image Super-Resolution by Descattering and Fusion, IEEE Access, Vol. 5, pp. 670-679, 2017
- [12] H. Lu, Y. Li, L. Zhang, S. Serikawa. Contrast enhancement for images in turbid water. Journal of the Optical Society of America A. Vol.32, No.5, pp. 886-93, 2015
- [13] H. Lu, Y. Li, S. Nakashima, S. Serikawa. Turbidity underwater image restoration using spectral properties and light compensation. IEICE Trans. Inf. & Syst. Vol. 99, No.1, pp. 219-227, 2016
- [14] Barnes, C., Shechtman, E., Goldman, D., Andfinkelstein, A. 2010.: The generalized patchmatch correspondence algorithm. Computer Vision–ECCV 2010, 29–43 (2010).
- [15] Z. Farbman, R. Fattal, D. Lischinski, and R. Szeliski.: Edgepreserving decompositions for multi-scale tone and detail manipulation [J]. ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH 2008), Aug.27(3) (2008)
- [16] Sean Bell, Paul Upchurch, Noah Snavely, Kavita Bala.: Material Recognition in the Wild with the Materials in Context Database. IEEE Conference on Computer Vision and Pattern Recognition, (CVPR) 2015, Boston, MA, USA, June 7-12 (2015)
- [17] Lischinski, D., Farbman, Z., Uyttendaele, M., And Szeliski, R.: Interactive local adjustment of tonal values [J]. ACM Trans. Graph., 25, 3 (July): 646-653 (2006)
- [18] Quan Zhou, Baoyu Zheng, Weiping Zhu, and Longin Jan Latecki. Multi-scale context for scene labeling via flexible segmentation graph. Pattern Recognition, 2016(59): 312-324, 2016.