TRANSFER OF VIGNETTING EFFECT FROM PAINTINGS TO PHOTOGRAPHS

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ABSTRACT

This paper addresses the aesthetic enhancement of the vignetting effect in photographs to follow such effect organization in example paintings. The example painting is selected based on a comparison of the contextual geometry of the painting and the photograph. Then an algorithm is developed to transfer the lightness weighting extracted from an example painting to a photograph to create the painter-style vignetting effect. Experiments show that the proposed algorithm can successfully transfer the vignetting effect from an example painting to a photograph. Meanwhile, the vignetting effect is more naturally presented with regard to aesthetic composition comparing with popular software tools and camera models.

Index Terms— Style transfer; Vignetting; Painting

1. INTRODUCTION

Vignetting is an effect that is clear in the center and fades off at the edges by reducing the image's brightness or saturation at the periphery in photography. The purposely introduced vignetting effect can create artistic effect, such as drawing attention of the viewer to the center of the image. In photographs, the effect can be created by camera settings or post-processing. This photo-style vignetting creates a clear circle in the image, see Fig. 1(a).

Artists also use vignetting in paintings by organizing center-corner contrast. The vignetting effect in paintings, which is called painter-style vignetting, helps to draw attention of the viewer to the center (in portrait) or guide the eye of the viewer to the far away scene (in landscape). The painter-style vignetting is naturally presented by gradually fading off the elements near the periphery and does not leave a definite line on the border of the paintings [1]. This painter-style vignetting can be produced by fading off two or three areas unevenly or symmetrically in the periphery of the painting. In the example paintings in Fig. 1(b)(c), the corners are willfully darkened to serve compositional needs. This vignetting is a common pictorial device well known to professional photographers and painters. This paper attempts to explore an algorithm to transfer this painter-style vignetting from paintings to photographs for the purpose of an artistic image enhancement. To our knowledge, this is first work that transfers vignetting effect from paintings to photographs.

(a) (b) (c)

Fig. 1. (a) Photograph with vignetting from [2]. (b) Albert Bierstadt, 1872. (c) Thomas Gainsborough, 1777-1780.

2. RELATED WORK

Most of the research on vignetting is for the correction of vignetting in photographs caused by camera settings or lens limitations [3, 2, 4]. For the creation of a vignetting effect in photographs, Samii et al. mentioned to stylize false vignetting effect in images [5]. This work was done by learning experts' artistic decision processes to enhance a new photograph. This learning method need a set of training data that maintained the history of adjustments applied to every photograph by experts. It was a challenging work to collect such training data, especially for pre-modern painting styles. For style transfer, Liu et al. proposed to transfer the vignetting effect along with the color transfer [6]. The vignetting function in an example image was modeled by a 6th-order even polynomial and it then was applied to the user's photo by simply multiplying each pixel of the photo by the vignetting function. This vignetting function was defined based on a camera vignetting model that affecting image pixels based on their distance from the optical center.

With the development of digital imaging techniques, vignetting has become a popular effect in some software tools, such as the "Lens Correction" filter in Photoshop, "Lo-fi" fil-

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ter in Instagram. However, these photo-style vignetting effects enforce a darker corner or edge without the consideration on the geometric structure of the image, and they create a clear unnatural circle around the image. Different from the work mentioned above, this paper proposes to learn the vignetting effect in an example painting by analyzing the spatial distribution of the lightness. Then, the learned lightness weighting pattern is adaptively transferred to the photograph.

3. TRANSFER OF PAINTER-STYLE VIGNETTING

By analyzing the vignetting effect in paintings, we observed that the vignetting effect in paintings is naturally presented by darkening objects on the periphery based on the geometry of the scene. The darkness on different objects are introduced differently and local contrast is preserved on dark objects. Based on this observation, we develop an algorithm to manipulate the vignetting effect in a photograph based on an example painting which is similar in content and geometry with the photograph. This paper focuses on the main photograph categories of landscape and portrait.

Given a photograph without vignetting, the objective of this paper is to create the vignetting effect. The objective can be formulated as

$$L_{out} = f(L, W) \tag{1}$$

where L is the lightness of the input photograph without vignetting, W is the lightness weighting. L_{out} is the lightness with vignetting effect. $f(\cdot)$ is the blending function. The main tasks of creating vignetting effect are to generate the lightness weighting W and define the blending function f. Based on the study from paintings, the definition of W and f should consider the following four criteria.

1. Selecting the lightness weighting pattern based on the contextual geometry
2. Enhancing the contrast between center and corner.
3. Preserving the local contrast on dark objects.
4. Darkening different objects differently.

3.1. Lightness weighting pattern and blending function

The selection of lightness weighting pattern is achieved by selecting an example painting from the painting database. Then, the lightness weighting pattern is extracted from the example painting. Based on the assumption that images similar in content and geometry could have similar lightness weighting on corners, the example painting having such similarity with the input photograph is selected. The example painting selection is achieved by using quantized SIFT features and spatial pyramid matching scheme. More details can be found in [7]. The recommended top ranked paintings have similar contextual geometry with the input photographs. The user can select one of the top ranked paintings as the example painting.

After selecting the example painting, its lightness weighting pattern is extracted by estimating the lightness bias field. Given an image Z with lightness bias, it can be modeled by the product of the bias-free image I and the bias field B. The value of the pixel i in Z can be expressed as

$$Z_i = I_i B_i \tag{2}$$

The task of bias field estimation is to estimate the bias field B together with I based on the value Z. This ill-posed problem can be formulated as an optimization problem based on the constraints on B and I. The estimation of B can be achieved by the following optimization function.

$$B' = \arg\max_B P(B \mid Z) \propto \arg\max_B P(Z \mid B)P(B) \tag{3}$$

The probability models of $P(Z \mid B)$ and $P(B)$ are constructed based on the sparseness priors of the gradient probability distribution in [8]. They are used to estimate the lightness bias field in this paper. The extracted lightness bias fields for three paintings with different contextual geometry are shown in Fig. 2. The lightness bias field presents a coarse lightness distribution in the 2D image plane. The estimated lightness bias field B' from the example painting is used as the initial lightness weighting for the input photograph.

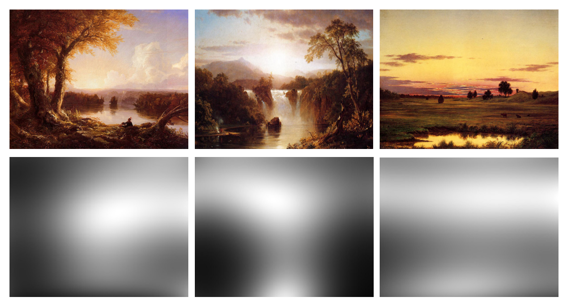

Fig. 2. The extracted lightness bias fields for three paintings.

After selecting the lightness weighting pattern, the challenge is projected to define a blending function while satisfying the criteria 2 to 4. By examining the blending techniques used in Photoshop, we find that the Overlay blending mode satisfies the criteria for the painter-style vignetting transfer. It brightens areas that are bright in the lightness weighting and darkens areas that are dark in the lightness weighting. It also darkens different objects differently based on their original values. In addition, the local contrast is preserved to some degree. Therefore we apply Overlay blending function to blend the lightness weighting with the lightness of input photograph. The formulation is

$$L'_{i,j} = \begin{cases} \frac{2W_{i,j}(N-L_{i,j})}{N} + 2L_{i,j} - N & \text{if } L_{i,j} > \frac{N}{2} \\ \frac{2W_{i,j}L_{i,j}}{N} & \text{otherwise} \end{cases} \tag{4}$$

where L is the lightness value of the photograph, W is the lightness weighting. L' is the output lightness after the blending. Here, W and L are in the same value range [0, N].

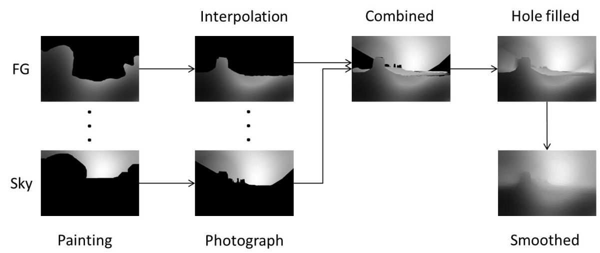

Fig. 3. Content-aware interpolation of the lightness weighting.

3.2. Content-aware interpolation

Although the selected example painting has similar contextual geometry with the input photograph, there are still some variations in the spacial organization of the structure. Therefore, instead of using the lightness weighting from the example painting directly, it is interpolated adaptively to fit the structure of the photograph.

As studied in [7], the important contextual structure in landscape images is dividing into depth planes for creating perception of depth, generally foreground (FG), middle-ground (MG), background (BG) and sky. For portrait images, the important contextual structure is composed by the face and skin areas (FS), the non-face/skin part of the figure (FO), and the non-figure region [9]. Therefore, the photographs and paintings are segmented to important contextual regions for the content-aware interpolation of the lightness weighting. The landscape images are divided to depth planes of FG, MG, BG and sky, and the portrait images are divided to FS, FO and the non-figure region. The segmentation of contextual regions is achieved by using interactive segmentation as in [7, 9]. The lightness weighting at each region is generated based on the lightness weighting of the corresponding region in the example painting.

Given the lightness weighting of one region in the example painting W_r, it is first registered with the corresponding region in the photograph. The registration is performed by a shifting and a scaling to make the regional center and size matched together. After getting the registered lightness weighting W_r^R, a surface S is constructed for the 3D points $(x, y, W_r^R(x, y))$. The lightness weighting of the corresponding region in the photograph is linearly interpolated from the surface S. Then, the lightness weighting of the photograph is generated by combing the lightness weighting for all the regions. Holes in the combined lightness weighting are filled by the linear interpolation using the data from the combined lightness weighting. Finally, a smoothed lightness weighting W is generated by using the edge-preserving smooth [10]. The smoothing is to keep the gradient of the lightness weighting as small as possible, unless the original lightness L has significant gradient. The effect of each step in the content-aware interpolation can be clearly seen in Fig. 3.

3.3. Local contrast restoration

Using the content-aware interpolated lightness weighting W and the blending mode $f(\cdot)$, the weighted lightness is calculated as $\tilde{L} = f(L, W)$. Although the Overlay mode can preserve the local details to some degree, the local contrast are still reduced in dark regions. In order to preserve the local details, an optimization function is used to restore the reduced local contrast in $\tilde{L}$. The lightness L_o with restored local contrast is calculated as

$$L_o = \arg\min_{L_o} \left[w_d (L_o - \tilde{L})^2 + w_g \|\nabla L_o - \nabla L\|^2 \right] \quad (5)$$

The first term is the constraint on the lightness value and the second term is the constraint on the gradient. Since gradient is one expression of local contrast, the output with the restored gradients has the local contrast of the original image. w_d and w_g are the weights for the two constraints. In the implementation, constant values are used for weights $w_d = 0.01, w_g = 1$. The minimization of function (5) can be achieved using standard or weighted least-squares techniques as in [7, 9].

4. EXPERIMENTS

In this section, the performance of our method is analyzed. The Hudson River landscape paintings collected in [7] and the portrait painting dataset collected in [9] were used as our painting database for the experiments. The test photographs were collected from the MIT-Adobe FiveK Dataset [11] and our personal collections. Two results generated by our method are shown in Fig. 4. The content-aware lightness weighting for both the landscape and portrait photographs are successfully generated by using our method, see Fig. 4 (d)(i). The experimental results with vignetting effect have a more distinct contrast between center and corner than the original photographs. The enhanced center-corner contrast produces a feel of depth in the landscape photograph and makes the figure stands out in the portrait photograph.

Comparison. In order to evaluate the advantage of our method, it is compared to the vignetting transfer model (Autostyle method) in [6], the vignette in Photoshop, and the "Lo-fi" filter in Instagram. Fig. 5 shows an example of the comparison. The result by vignetting transfer in [6] has no clear difference from the original photograph. This is because the estimated vignetting from the example painting by the model in [6] is very weak. The vignetting model in [6] is designed for camera vignetting effect and does not work for painter-style vignetting. The vignette in Photoshop only darkens the pixels based on their distance from the center. All the pixels in the same distance are darkened in the same way, no matter whether they are sky or ground pixels. There is a clear circle in the result. The "Lo-fi" filter in Instagram darkens the periphery pixels and also brightens the center. The pixels close to the periphery are enforced to be dark without consideration about the content. There is also a clear circle in the result.

Fig. 4. (a) and (f) Example paintings, (b) and (g) Input photographs, (c) and (h) Lightness weighting of (a) and (f), (d) and (i) Content-aware lightness weighting for (b) and (g), (h) and (j) Results.

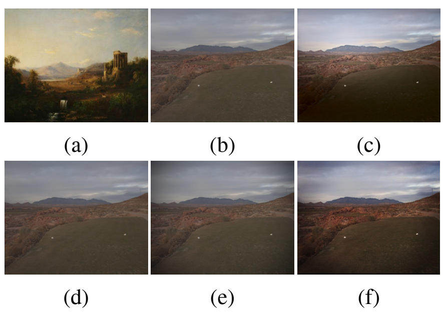

Fig. 5. Comparison. (a) Example painting, (b) Input photograph, (c) Result by our method, (d) Result by Autostyle [6], (e) Vignette in Photoshop, (f) "Lo-fi" filter in Instagram.

Differently, the vignetting effect in the result by our method (Fig. 5(c)) is more naturally presented without a clear circle. Regions are also darkened in different degrees following the aesthetic composition in the example painting.

User study. In order to significantly evaluate the advantage of our method, a user study was conducted to compare the vignetting effect created by our method with those by Autostyle [6], vignette in Photoshop, and "Lo-fi" filter in Instagram. 25 test photographs were randomly selected for this user study. The participants connected to the user study webpage using their own computers and monitors. The results obtained by our method and one of other methods were shown as a pair side by side in randomly generated order. The participants were asked to answer two questions, Q1: "Which image has more naturally presented vignetting effect? " and Q2:"Which image is more visually pleasing?". They could choose "Left" or "Right" as a response. There were a total of 28 participants aged from 18 to 35. 12 of them were male and 16 of them were female. For each comparison, 700 responses

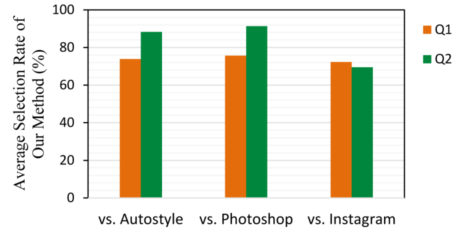

Fig. 6. The user study result.

were collected. The user study result is summarized in Fig. 6. It shows that our results are preferred by a significantly higher percentage of responses (larger than 70%) than those by other methods. The vignetting effect created by our method is more naturally presented which results in pleasing visual appearance. Additionally, our results are also compared to original photographs on the visual appearance. 84.8% of the responses select our results as more visually pleasing than original photographs. More experimental results are shown in Fig. 7.

Fig. 7. More experimental results. From left to right: input photographs, lightness weighting, results.

5. CONCLUSION

This paper develops an algorithm to transfer the painter-style vignetting from paintings to photographs. First, the lightness weighting pattern is extracted from the selected example painting. Then, the Overlay mode is applied to blend the lightness weighting pattern with the original lightness to enhance the center-corner contrast. A content-aware interpolation method is proposed to warp the lightness weighting to fit the contextual structure of the photograph. It makes the algorithm robust to the variation of the contextual geometry between the example painting and the input photograph. Finally, the local contrast is restored. Experimental results and a user study show that our method performs better than popular software and camera models in generating vignetting effect.

6. REFERENCES

[1] Rose Edin and Dee Jepsen, *Color Harmonies: Paint Watercolors Filled with Light*, North Light Books, an imprint of F+W Media, Inc., 2010.

[2] Yuanjie Zheng, Stephen Lin, Sing Bing Kang, Rui Xiao, James C. Gee, and Chandra Kambhamettu, "Single-image vignetting correction from gradient distribution symmetries," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 35, no. 6, pp. 1480 – 1494, 2013.

[3] Dan B Goldman, "Vignette and exposure calibration and compensation," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 32, no. 12, pp. 2276 – 2288, 2010.

[4] Hojin Cho, Hyunjoon Lee, and Seungyong Lee, "Radial bright channel prior for single image vignetting correction," in *Proc. of European Conference Computer Vision*, 2014, pp. 189–202.

[5] Armin Samii and Tim Althoff, "Iterative learning: Leveraging the computer as an on-demand expert artist," *CS281A Statistical Learning Theory (Michael Jordan and Martin Wainwright) and CS294-69 Image Manipulation and Computational Photography (Maneesh Agrawala),University of California, Berkeley*, pp. 1–11, 2011.

[6] Yiming Liu, Michael Cohen, Matt Uyttendaele, and Szymon Rusinkiewicz, "Autostyle: Automatic style transfer from image collections to users' images," *Computer Graphics Forum*, vol. 33, no. 4, pp. 21 – 31, 2014.

[7] Xiaoyan Zhang, Kap Luk Chan, and Martin Constable, "Atmospheric perspective effect enhancement of landscape photographs through depth-aware contrast manipulation," *IEEE Transactions on Multimedia*, vol. 16, no. 3, pp. 653 – 667, 2014.

[8] Y. Zheng, M. Grossman, S. Awate, and J. Gee, "Automatic correction of intensity nonuniformity from sparseness of gradient distribution in medical images," in *Proc. of the 12th International Conference on Medical Image Computing and Computer Assisted Intervention*, September 2009, pp. 852–859.

[9] Xiaoyan Zhang, Martin Constable, and Kap Luk Chan, "Exemplar-based portrait photograph enhancement as informed by portrait paintings," *Computer Graphics Forum*, vol. 33, no. 8, pp. 38–51, 2014.

[10] Zeev Farbman, Raanan Fattal, Dani Lischinski, and Richard Szeliski, "Edge-preserving decompositions for multi-scale tone and detail manipulation," *ACM Transactions on Graphics*, vol. 27, no. 3, pp. 67:1–67:10, 2008.

[11] Vladimir Bychkovsky, Sylvain Paris, Eric Chan, and Frédo Durand, "Learning photographic global tonal adjustment with a database of input / output image pairs," in *Proc. of IEEE Conference on Computer Vision and Pattern Recognition*, 2011, pp. 97–104.