

Color Constancy using Superpixel

Xingsheng Yuan, Zhengzhi Wang

Abstract—Color constancy algorithms are generally based on the simplified assumption about the spectral distribution or the reflection attributes of the scene surface. However, in reality, these assumptions are too restrictive. The methodology is proposed to extend existing algorithm to applying color constancy locally to image patches rather than globally to the entire images.

In this paper, a method based on low-level image features using superpixels is proposed. Superpixel segmentation partition an image into regions that are approximately uniform in size and shape. Instead of using entire pixel set for estimating the illuminant, only superpixels with the most valuable information are used. Based on large scale experiments on real-world scenes, it can be derived that the estimation is more accurate using superpixels than when using the entire image.

Keywords—color constancy, illuminant estimation, superpixel

I. INTRODUCTION

THE color of an object tends to be biased toward the color of the illuminant in the scene. Color shift of the perceived color from the genuine color usually causes problems in identifying the objects in the scene. Fortunately, human vision system has the color constancy capability to correct color deviation caused by a difference in illumination. Color-based features are usually of great use in computer vision, such as object tracking and object recognition, making color constancy a necessity for machine vision.

Many color constancy algorithms have been proposed in the last few years [1]. Color constancy algorithms are generally divided into two major groups: algorithms based on low-level image features and algorithms that use information acquired in a learning phase to estimate the illuminant. Gamut-based [2]-[3] methods are examples of the latter group. Examples of methods using low-level features are the well-known white-patch algorithms [4] and Grey-world algorithms [5].

Focusing on the low-level driven color constancy, one of the drawbacks of White-Patch and the Grey-World algorithms is that they are highly dependent on the validity of their assumption. For instance, White-Patch based on the assumption that the maximum response in a scene is caused by a perfect reflectance. Grey-world algorithm assumes the average edge difference in a scene is achromatic.

In reality, not all pixels contain relevant information for color constancy methods, furthermore, biased pixel values may decrease the performance of these color constancy methods [6].

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Instead of using the entire image to estimate the illuminant, the method is proposed using only that part of the image which contains the most valuable information for color constancy.

This paper will introduce a color constancy method using superpixels [7], which represent a restricted form of region segmentation by which the pixels with the same visual appearances are grouped.

II. COLOR CONSTANCY

Color constancy is a two stage procedure: the scene illuminant is estimated from the image data and then the image colors are transformed on the basis of this estimate to generate a new image of the scene as if it were taken under a canonical illuminant.

Assume that an image $\mathbf{f} = (f_R, f_G, f_B)^T$ is composed of:

$$\mathbf{f}(\mathbf{x}) = \int_{\omega} I(\lambda)\mathbf{p}(\lambda)S(\mathbf{x}, \lambda)d\lambda \quad (1)$$

Where $I(\lambda)$ is the color of light source, $S(\mathbf{x}, \lambda)$ is the surface reflection and $\mathbf{p}(\lambda)$ is the camera sensitivity function.

Further, λ is the wavelength of the light and \mathbf{x} is the spatial coordinate of Lambertian surface [8] and ω is the visible spectrum. Assuming that the scene is illuminated by one light source and that the observed color of the light source \mathbf{e} can be represented as:

$$\mathbf{e} = \begin{pmatrix} e_R \\ e_G \\ e_B \end{pmatrix} = \int_{\omega} I(\lambda)\mathbf{p}(\lambda)d\lambda \quad (2)$$

Color constancy can be achieved by estimating the color of light source \mathbf{e} , given the image values of \mathbf{f} , followed by a transformation of the original image values using this illuminant estimate:

$$\mathbf{f}_t = \mathcal{D}_{u,t}\mathbf{f}_u \quad (3)$$

Where \mathbf{f}_t is the image taken under an unknown light source, \mathbf{f}_u is the same image transformed, and $\mathcal{D}_{u,t}$ is a diagonal matrix which maps colors that are taken under an unknown light source to their corresponding colors under the canonical illuminant.

White-Patch and Grey-World are two well known color constancy algorithms, which are based on low-level features.

They are both derived from the Retinex theory proposed by Land and McCann [9]. In [10], the white-patch and Grey-world algorithm were incorporated into the more general framework, together with higher-order statistics (i.e image derivatives), resulting in one color constancy algorithm with three parameters:

$$\left(\int \left| \frac{\partial^n \mathbf{f}^\sigma(\mathbf{x})}{\partial \mathbf{x}^n} \right|^p d\mathbf{x} \right)^{\frac{1}{p}} = \kappa e^{n,p,\sigma} \quad (4)$$

Where n is the order of the derivative, p is the Minkowski-norm and $\mathbf{f}^\sigma = \mathbf{f} \otimes G^\sigma$ is the convolution of the image with a Gaussian filter with scale parameter σ .

III. ILLUMINANT ESTIMATION USING SUPERPIXEL

The main idea of using image parts or regions when estimating the illuminant is that certain parts of image do not contribute to a robust estimate of the illuminant [6]. Therefore, instead of using the entire image, it is necessary to apply segmentation to get the pixel groups with the most reliable information for color constancy. Superpixel segmentation partition an image into regions that are approximately uniform in size and shape, provided that superpixel size is comparable to the size of the smallest target region. In this paper, superpixel is achieved by designing a geometric flow [7] that dilates an initial set of uniformly distributed seeds, where each seed corresponds to one superpixel.

In Fig1, superpixel segmentation is given, that the image is segmented into 1500 superpixels. Each superpixel shows the same visual appearance, see Fig 1(d). And for every superpixel, the illuminant is estimated using one single algorithm. In this case, superpixels of the image that negatively affect the estimation of the illuminant are ignored in the computation.

To summarize, the algorithm consists of the following steps:

- 1) Get the superpixels of the image by over-segmentation.
- 2) Estimate the illuminant by using one of the algorithms based on low-level image features for all image superpixels.
- 3) Determine the superpixels with the most reliable information to estimate the illuminant. Transform the original image values using this illuminant estimate.

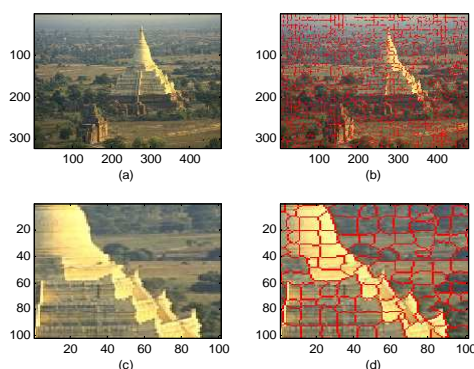


Fig. 1 superpixels obtained by Geometric Flows

IV. EXPERIMENTS

Superpixels are grouping of pixels with the same visual appearance. Therefore, it is easy to get the parts of images contain more valuable information and get rid of the information that may ruin the estimation.

Data set : In this section, the algorithm is tested on the data set introduced by [11]. This data set contains 11,000 images, including indoor, outdoor, desert, cityscape, and other settings. The proposed algorithm is tested using a number of images of different categories. In total, 60 images from 4 clips of the complete data set (15 images per category) were annotated as open country, 60 images from 6 clips (10 per category) as road and also 60 images from 6 clips as indoor (10 per category).

Performance Measure : To measure how close the estimated illuminant resembles the true color of the light source, the angular error \mathcal{E} is used:

$$\mathcal{E} = \cos^{-1} \left(\frac{e_e * e_t}{\|e_e\| \times \|e_t\|} \right) \times \frac{180^\circ}{\pi} \quad (5)$$

Where e_e is estimated illumination, and e_t is measured actual illumination chromaticity. To measure the performance of an algorithm, the mean error as well as the media error is considered [12].

TABLE I
 PERFORMANCE OF THE COLOR CONSTANCY FRAMEWORK (4) WITH FIXED
 PARAMETER SETTING: $e_{0,1,0}$

	Mean	Media
Open country		
Entire image	6.90°	5.05°
Proposed-Method	3.27°	2.54°
Indoor		
Entire image	22.32°	22.93°
Proposed-Method	10.76°	10.61°
Road		
Entire image	8.63°	9.90°
Proposed-Method	4.58°	4.11°

In Table I, the results of the method using the entire image and the method using superpixel segmentation are shown. The performance is considerably better when using superpixel segmentation than when using the entire image. The mean error decreases about 50%. The mean angular error of specific categories, like road and open country, is much smaller than indoor images. That may be caused by the low local edge contrast of indoor images. In Fig.2, Grey-world algorithm and method using superpixel segmentation are tested by images obtained from three image categories (Open country, Road and Indoor) separately. The visual appearance of the results also verifies that the superpixel segmentation method is much better. The ground truth is acquired by making use of the small grey sphere in the bottom right corner of the images. Note that the grey ball in the image is masked while estimating the illuminant.

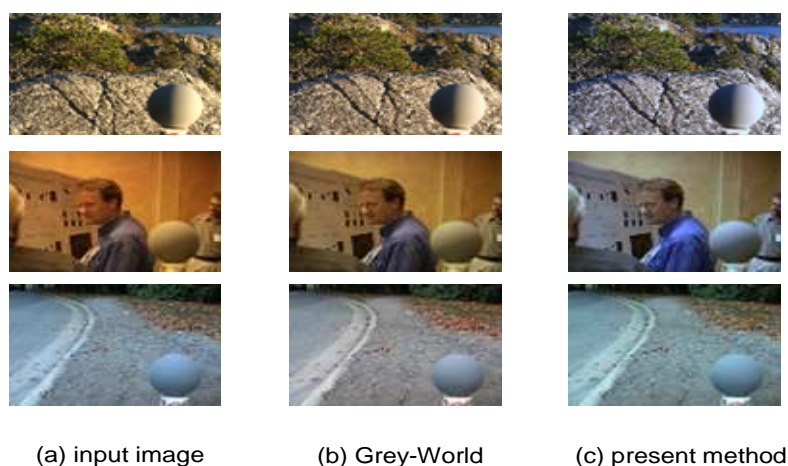


Fig. 2 Corrected images using (b) Grey-world method and (c) presented method

V. CONCLUSION

In this paper, we proposed a color constancy method based on low-level image features using superpixels. Over-segmentation is performed to learn for different categories which superpixel is most appropriate for a reliable estimation. Experiments applied on real-world images show that the estimation is more accurate using superpixels of the image than when using the entire image. The performance of specific categories, like *road* and *open country* images, the estimation error is smaller than the *indoor* images. The corrected images also show that the visual appearance is much better when using superpixels segmentation than when using the entire image.

REFERENCES

- [1] A Gijzen, T Gevers, J v d Weijer, "Computational color constancy: Survey and Experiments," *Trans. Image Processing*, 2011, vol. 20, pp.2475-2489, sept. 2011.
- [2] G. D. Finlayson, S. D. Hordley, and P. M. ubel, "Color by correlation: a simple, unifying framework for color constancy," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol.23, pp.1209-1221, Nov.2001.
- [3] G. D. Finlayson, S. D. Hordley, I. astl, "Gamut constrained illuminant estimation," *Int.J. Computer Vision*, vol.67, no.1, pp.93-109, 2006.
- [4] E. H. Land, "The retinex theory of color vision," *Scientific American*, vol.237, pp.108-128, Dec. 1977.
- [5] G. Buchsbaum, "A spatial processor model for object colour perception," *Journal of the Franklin Institute*, vol.310, pp.1-26, July 1980.
- [6] A. Gijzen, and T Gevers, "Color constancy using image regions," in *Conf.Rec.2007 IEEE Int Conf. Image Processing*, pp.501-504.
- [7] L Alex, S Adrian, Kiriakos N. Kutulakos, David J. Fleet, Sven J. Dichinson and Kaleem Siddiqi, "TurboPixels: Fast superpixels Using Geometric Flows," *IEEE Trans. Pattern Analysis and Machine Intelligence*, vol..31, pp.2290-2297, Dec.2009.
- [8] S. A. Shafer, "Using color to separate reflection components," *Color Research and Application*, vol. 10, pp. 210-218, Dec.1985.
- [9] H. L. Edwin and J McCann., "Lightness and retinex theory," *J. Opt. Soc Am*, vol.61, pp.1-11, Jan. 1971.
- [10] J v d Weijer, T Gevers, and A Gijzen, "Edge-based color constancy," *Trans. Image Processing*, vol.16, pp.2207-2214, Sept. 2007.
- [11] F Ciurea and B.V. Funt, "A large image database for color constancy research," in *Proc. Eleventh Color Imaging Conf. IS&T- The Society for Imaging Science and Technology*, Scottsdale, Arizona, 2003, pp. 160-164.
- [12] S.D. Hordley and G.D. Finlayson, "Reevaluation of color constancy algorithm performance," *J. Opt. Soc Am*, vol. 23, pp. 1008-1020, Nov. 2006.

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