Illumination Estimation for Color Constancy Using Convolutional Neural Network (CNN)

HO-HYOUNG CHOI[1] AND BYOUNG-JU YUN[2]
1: Advanced Dental Device Development Institute (A3DI), Kyungpook National University, 2177 Dalgnbeol-daero, Jung-gu, Daegu 41940, REPUBLIC OF KOREA

2: School of Electronic Engineering, College of IT Engineering, Kyungpook National University, Daegu 41566, REPUBLIC OF KOREA

chhman2000@msn.com and bjisyun@ee.knu.ac.kr

Abstract: - In color constancy research, one of the well-studied problems is how to estimate and remove scene illumination chromaticity from image data. Throughout several decades, illuminant estimation methods have been developed by many researchers and institutions as evidenced in literature. These methods have yet to overcome several color distortion problems such as color leakage, luminance shift, hue shift and so forth.
Accordingly, this article proposes an illuminant estimation method that combines preprocessing and CNN to achieve color constancy. The preprocessing uses an average image to normalize a given input image as a method of addressing both varying illumination and uneven background from a real-life scene image. A 3-layer CNN architecture is then used to estimate scene illumination efficiently. Given image patches as input data, the CNN works in a spatial domain, which does not require taking hand crafted features usually adopted for conventional methods. To create a more effective model for estimating scene illumination, the proposed method integrates feature learning and regression to institute one optimization process within the network structure. The experimental results prove that the proposed method delivers better performance of predicting scene illumination for color constancy over the conventional methods.

Key-Words: color constancy, estimating scene illumination chromaticity, CNN architecture, feature learning, feature regression, optimization process, network structure

1 Introduction

Human eyes are analogous to the source illuminant and can see the true colors of objects, whereas digital images are often influenced by the color of the prevailing illuminants, the intrinsic reflectance properties of the objects and the sensitivity function of the imaging devices. These factors cause the captured images to exhibit color cast, rather than presenting the actual colors of the objects. For instance, as illuminations having different spectral power distributions reach any object, two different illumination effects can occur. Color constancy is a phenomenon of the human eyes to perceive colors of an object under different illuminations as relatively identical. The digital imaging devices use computational color constancy algorithms to recover the color of the object under canonical illumination. Common computational color constancy algorithms estimate the illuminant chromaticity from the captured image and correct the extrinsic illuminant biased image[1]. Therefore, the goal of color constancy algorithm is to remove the color casts from the image and manifest the actual colors of the objects by preserving constant distribution of the light spectrum across the digital image so that the image appears as if it has been taken under a canonical source illuminant [2], [3].

To do this, there are many illuminant estimation methods proposed by researchers and institutions through literatures, and these methods are classified into three categories: low-level statistical methods, gamut-based methods and learning-based methods.

However, those methods deliver higher performance but they have yet to overcome several problems including luminance shift, hue shift, and white balance and so forth.

Accordingly, this article proposes an illumination estimation method which consists of the preprocessing and CNN. The preprocessing normalizes the given input image with the average image to address both varying illumination and the uneven background from the real-life scene image. The resulting image is then processed by the CNN which has learned discriminant features to perform illuminant estimation task. Recently, deep neural networks have gained attention of numerous researchers who adopted the conventional approaches to the performance of various computer vision tasks [4], [5]. One of the CNN's advantages is that it can take raw image as input and incorporate feature learning into training process. With a deep structure, CNN can learn complicated mappings while requiring minimal domain knowledge. For this reason, CNN is adopted to efficiently estimate illuminants of the real-life scene image.

2 Proposed Method

As other part of the proposed method, the CNN trained on discriminant features uses the resulting image from preprocessing to perform illumination estimation task. The CNN in the proposed method contains three convolutional layers with each layer specifically tasked, quite similar to the CNN structure proposed by Dong et al [6], and Figure 1 shows the block diagram for the proposed method.

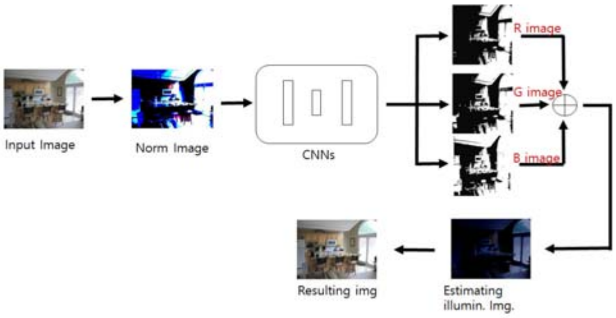

Fig.1. The block diagrgam for the proposed method.

The correction (or color constancy image) is described as follows:

$$\hat{I}_{i,out} = (\hat{I}_{i,input}\hat{M}); i \in \{R, G, B\} \tag{1}$$

where $\hat{I}_{i,out}$ and $\hat{I}_{i,input}$ are the corrected and test input images. $\hat{M}$ is a diagonal matrix given by:

$$\hat{M} = \begin{bmatrix} 1/\hat{r} & 0 & 0 \\ 0 & 1/\hat{g} & 0 \\ 0 & 0 & 1/\hat{b} \end{bmatrix} \tag{2}$$

where $\hat{r}$, $\hat{g}$, and $\hat{b}$ are red, green and blue values of the estimated illumination color from CNN architecture, respectively

3 Experimental result and evaluations

To experiment the proposed method and compare the result with those of conventional methods, three benchmark image datasets including Barcelona Images, Yaccd2dataset, and Cube dataset were selected to train the illumination image patches.

The experimental results, Figure 2, are generated by applying the proposed method together with state-of-the-art and other conventional color constancy methods such as Gray-World, max-RGB (White patch (WP)), Shades of Gray, Gray-Edge (GE), Weighted Gray Edge (WGE) and Color Cat (C.C). (a) shows the original image, taken from ADE20K dataset as a test dataset37, and includes indoor and outdoor images. From (b) to (g), each image shows the resulting image from the conventional methods. The matlab codes with respect to each method are implemented according to suggestion in each of the reference. The resulting images still have several problems such as color leakage, luminance shift, color balance, hue shift and so on. In addition, blue color constancy takes place in the entire resulting image, especially in the resulting image of the GW and C. C methods. (h) shows the resulting image from the proposed method. The contrast of the resulting image is significantly improved without color distortion problems.

Table 1. Performance of different color constancy method (lower is better)

	min	**mean**	**median**	**trimean**	**best 25**	**worst 25**	**max**
GW	2.02	23.42	24.98	22.34	2.51	45.65	59.45
WP	1.03	10.99	7.71	8.51	1.12	25.77	46.91
SoG	1.93	24.97	27.67	24.59	2.08	48.27	62.03
GE	1.16	17.25	17.88	16.38	1.48	35.03	48.24
WGE	2.15	20.94	20.39	19.27	2.48	41.58	57.72
C.C	2.70	25.00	24.50	23.77	4.87	48.02	61.87
pro	**1.16**	**9.44**	**6.01**	**6.78**	**1.96**	**23.64**	**45.8**

(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 2. Experimental resulting image with input_4, (a) original image, (b) Gray-World, (c) max-RGB, (d) Shades of Gray, (e) Gray-Edge, (f) Weighted Gray Edge, (g) Color Cat, (h) proposed method.

Table 1 compares the error results of the conventional methods and the proposed method. The resulting indicator shows the proposed method produces a lower value than the conventional methods.

4 Conclusion

The objective of a color constancy algorithm is to remove color casts from images and manifest the actual colors of the objects by preserving constant distribution of the light spectrum across the digital images. During past decades, color constancy algorithms have been proposed by many researchers and institutions. However, the conventional methods have yet to overcome several problems such as color shift, hue shift, color leakage and so forth.

Accordingly, this article proposes an illuminant estimation method which consists of the two parts: preprocessing and CNN. In the experimental results, the color shift and luminance shift problems are remarkably solved as shown in the gamut area test. In addition, the proposed method recorded a lower score in the error measurement.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(NRF-2019R1I1A3A01061844 and NRF-2018R1D1A1B07040457)

References:

[1] D.H. Foster, “Color Constancy,” Vision Resarch, vol. 51, no. 7, pp.674-700, 2011.

[2] A. Gijsenij, T. Gevers, and J.Van De Weijer, “Computational Color Constancy: Survey and Experiments,” IEEE Trans. Image Process., vol. 20, no. 9, pp. 2475-2489, 2011.

[3] N. Banic and S. Loncric, “Color cat: Remembering Colors for Illumination Estimation,” IEEE Signal Process. Lett, vol. 22, no. 6, pp. 651-655, 2015.

[4] K. Kavukeuoglu, P. Sermanet, Y.-L. Boureau, K. Gregor, M. Mathieu, and Y. L. Cun, “Learning convolutional feature hierarchies for visual recognition,” In Advances in neural information processing systems, pp. 1090-1098, 2010.

[5] A. Krizhevsky, I. Sutskever, and G. E. Hinton, “Imagenet classification with deep convolutional networks,” In Advances in neural information processing systems, pp.1097-1105, 2012.

[6] Chao Dong, Chen Change Loy, Kaiming He and Xiaoou Tang, “Image Super-Resolution Using Deep Convolutional Networks,” in: IEEE Conference on Computer Vision, pp. 579-584, 2015.