Laplacian of Gaussian Based on Color Constancy Algorithm for Surrounding Image Stitching Application

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***Abstract*—This paper presents a new algorithm for Laplacian of Gaussian (LoG) image processing systems. In order to improve nowadays digital capture system and digital display calibration. Color constancy is added to improve the measurement of object color based on independent light sources. To satisfy the human eye's recognition of colors, the angular error must be corrected to make the light source reflect naturally in the image. In addition, the hardware design of classic white balance algorithms such as Gray-World, Max-RGB, and Gray-Edge with the Minkowski norms is implemented in this study. The proposed algorithm is simulating with a Gaussian filter and an additional Laplacian of Gaussian (LoG) to generate real-time masks that automatically brighten images. Compared with several previous studies, the proposed algorithm shows lower angular errors while maintaining the quality of the graphics. The motivation is to make better quality watches on display facilities and better capture systems.**

Keywords—White Balance, Color Constancy, Gaussian filter, Laplacian of Gaussian(LoG), Gray-World, Max-RGB, Gray-Edge, Minkowski norm, Angular error

I. Introduction

The color of an object usually defines the light source with the human eye, and the color constancy tends to affect digital images. These include the light source, the surface reflectivity of objects, and the sensing capabilities of the capture system. The factors affect the definition of color to reflect single capture systems, such as the human eye or digital camera, which restores the exact light source irradiated on each object. Applying the assumptions of Gray-World, Max-RGB, and Gray-Edge algorithms contained in a series of color constancy proposed by [1][2][3]. Modify the pixels toward the illuminant direction, the image set to ideal color and edge weights. Add light source estimation and edge detection based on image information, and calculate global adjustment variables. Use the Gaussian filter on homogenizing [4] and use the Laplacian of Gaussian (LoG) image enhancement [5][6] is added to improve the brightness of the whole image. Finally, the image is deblurred and restored. The main purpose is to improve the visual facilities and reduce the variation of image angular error caused by improper light source angle. Apply it to an image processing system.

II. White Balance Algorithms

This paper gathered three major color constancy methods based on the following algorithm assumptions. The proposed algorithm consists of three steps. Initially is to adjust the image with the main algorithm. The second step is to apply a Gaussian filter and dilate the brightness region. The last step is to enhance the image details. Adjust the brightness much better with the LoG algorithm simplified operators.

A. Color Constancy Assumptions

The original color constancy is a phenomenon based on Lambertian surface, in which each of the image values is derived by $\mathrm{f} = (f_R, f_G, f_B)^T$ as shown in Equ. (1).

$$\mathrm{f} = \int_{\omega} I(\lambda)s(\lambda,x)c(\lambda)d\lambda \tag{1}$$

Where $I(\lambda)$ is the light source, $s(\lambda)$ is the surface reflectivity, ω is the wavelength, and $c(\lambda)$ is the capture system sensitive to wavelength [2].

With a series of assumptions, Finlayson and Trezzi [7] proposed a method by using constrained Minkowski norms p in illuminant estimation in Equ. (2).

$$\left(\frac{\int (f(x))^p dx}{\int dx}\right)^{\frac{1}{p}} = ke \tag{2}$$

The Gray-World, White-Patch, and Gray-Edge algorithm assumptions respectively represent $p = 1$, $p = \infty$, and $p = 6$ as the best results in [3]. The proposed algorithm referred to the PSNR (Peak signal-to-noise ratio) [8] values as an objective image quality index. Finally, we choose the best image quality by selecting the best PSNR value and sending it to the next step.

B. Processing to Decrease Angular Error

Angular error is an index used in illuminant estimation [2] to calculate the image illuminant angle between the actual light ℓ_a and assumed white light ℓ_e, as shown in Equ. (3).

$$err = cos^{-1}\left(\frac{(\ell_a \cdot \ell_e)}{\|\ell_a\|\|\ell_e\|}\right), \ell_e = \frac{1}{\sqrt{3}}(1,1,1)^T \tag{3}$$

Anisotropic Gaussian filtering [6] is used to fast obtain the edge and ridge maps to analyze the directional scale-space by using the applicability features. The proposed algorithm applies a one-dimensional Gaussian filter in the x and y directions to reduce the image details of the processed images.

$$g_x(x;\sigma_x) = \frac{1}{\sqrt{2\pi\sigma_x}} exp\left(-\frac{1}{2}\frac{x^2}{\sigma_x^2}\right) \tag{4}$$

$$y = xtan\varphi \tag{5}$$

By using Equs. (4) and (5), the image details can be

anisotropically smoothed in the φ-direction. Furthermore, the proposed algorithm includes a dilation mask for Gaussian filter homogenization. As shown in Fig. 1, to set the value of 0 with the condition of detected the image values which were 255 and dilation. During Gaussian filtering, the global image mask becomes more uniform. Homogenized the whole image in the first mask, the gradient of the threshold is compared with the image edges regarding the Laplacian of Gaussian (LoG) operation [6].

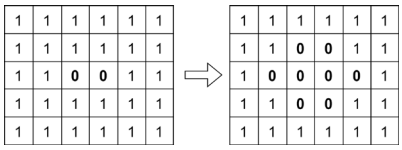
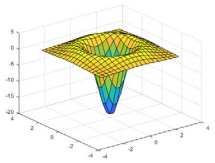


Fig. 1. Dilation with the image condition value of 255 in region.

C. *Laplacian of Gaussian (LoG) with simplified operators*

The LoG operator [6] is defined by (6) as shown in Fig. 2(a). The simplified operators of the LoG equation are shown in Fig. 2(b) to improve the image illuminant and enhance the brightness region of images. To improve the image illuminant and enhance the details of the image. Apply the simplified 5×5 matrix operators to make processed image brightness produces larger amplitudes. The image obtains detail enhancement and starts to deblur back and restore the image.

$$LoG(x,y) = -\frac{1}{\pi\sigma^4}\left[1-\frac{x^2+y^2}{2\sigma^2}\right]e^{\left(-\frac{x^2+y^2}{2\sigma^2}\right)} \quad (6)$$



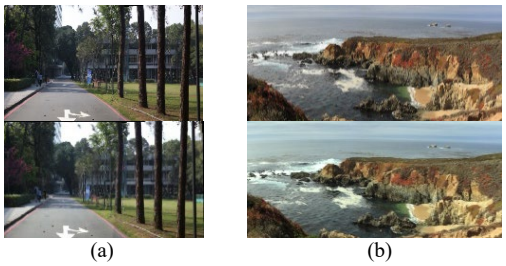
0	0	1	0	0
0	1	2	1	0
1	2	-16	2	1
0	1	2	1	0
0	0	1	0	0

(a) (b)

Fig. 2. (a) LoG operator schematic (b) Simplified as a 5×5 matrix operators.

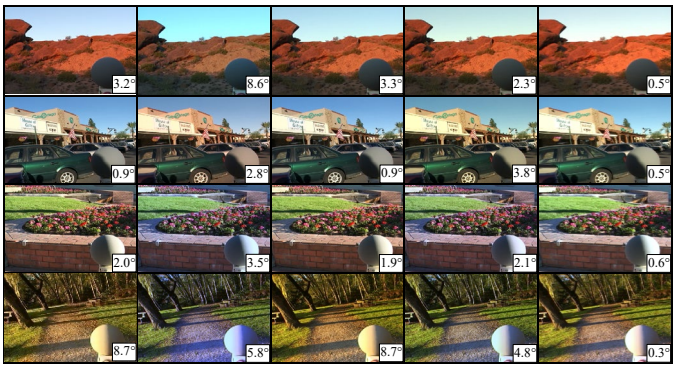
III. Results and Analysis

The proposed method applies two surrounding test images. The results shown in Figures 3 and 4 show the color constancy for the dataset [1] using different methods. TABLE I lists the angular error results of different methods. The proposed method analyzed the results with TABLE I, it reduced the angular error more than in previous studies [1][2][3]. The results show that each average compared with the proposed algorithm has greatly reduced the angular error.



(a) (b)

Fig. 3. Surrounding images processed by using the proposed algorithm. The upper one is the original image, and the down one is processed image (a) Coast (b) Road.



(a) (b) (c) (d) (e)

Fig.4 Different methods for dataset [1]: (a) Original [1] image (b) Gray-World [2] (c) White-Patch [2] (d) Gray-Edge [3] (e) Proposed method.

TABLE I
Angular errors with classical and proposed methods by using dataset [1]

	Original [1]	Gray-World [2]	Max-RGB [2]	Gray-Edge [3]	This Work
Mountain	3.2341	8.6120	3.3336	2.3047	0.5331
Buildings	0.9645	2.8607	0.9645	3.8790	0.5331
Parterre	2.0392	3.5603	1.9287	2.1254	0.6405
Forest	8.7789	5.8214	8.7789	4.8396	0.3854
Average	3.7541	5.2136	3.7514	3.2871	0.5230

IV. Conclusions

This paper presents a color constancy algorithm that combines the LoG algorithm and dilation to expand brighter pixels in an image. In addition, to improve the detection performance, Gaussian filtering and a simplified LoG operator are used to reduce the details of the whole image and improve the details of the white light area. The results show that the angular error is greatly reduced compared to previous studies. This work improved the stitching images' correct light angle.

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