An Image Illumination Correction Algorithm based on Tone Mapping

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***Abstract*—Illumination is an important factor to affect image quality in computer vision. In order to effectively weaken the influence of illumination on image quality, an image illumination correction algorithm based on tone mapping is proposed in this paper. The proposed algorithm combined color space decomposition and tone mapping based image brightness adjustment, which can improve the image contrast while maintaining the better color of the original image, and cannot increase noise. On the other hand, this algorithm is based on the pixel processing and does not need image transformation and image statistics information, which can reduce the computational complexity and more easily implement in hardware. Finally, a large number of experiments show that the proposed algorithm can effectively remove the impact of illumination and enhance image quality.**

Keywords-illumination correction; tone mapping; brightness adjustment; color space decomposition

I. INTRODUCTION

Illumination field inhomogeneity strongly affects the visual appearance of an image. It has a major influence on automatic information extraction within an image and illumination correction is therefore one of the first preprocessing steps required prior to the image analysis task [1]. The last years have seen great progress in this area. Currently, it has already exited many methods to different illumination correction: histogram equalization, homomorphic filtering, gamma correction. These methods can to some extent enhance the image contrast and light. A. Nayak and S. Chaudhuri[2] device an automatic correction scheme that transforms images under some unknown illumination to match an illumination model learnt for a known illumination. This approach enables a reliable tracking of hand in image sequences with wide variations in illumination. Several illumination correction methods have been proposed for face recognition on illumination conditions created in a laboratory. But B. Boom, L. Spreeuwers, and R. Veldhuis's[3] focus is more on uncontrolled conditions. They use the Phong model which allows modeling ambient light in shadow areas. By estimating the face surface and illumination conditions, they are able to reconstruct a face image containing frontal illumination. The reconstructed face images give a large improvement in performance of face recognition in uncontrolled conditions.

Tone mapping is a technique used in image processing and computer graphics to map one set of colors to another, often to approximate the appearance of high dynamic range images in a medium that has a more limited dynamic range. Print-outs, CRT or LCD monitors, and projectors all have a limited dynamic range which is inadequate to reproduce the full range of light intensities present in natural scenes. Essentially, tone mapping addresses the problem of strong contrast reduction from the scene values (radiance) to the displayable range while preserving the image details and color appearance important to appreciate the original scene content [4]. In recent years, this technology has received considerable attention [5-8].

This paper applies tone mapping technology to the region of illumination correction and presents a method for illumination correction based on tone mapping. The proposed algorithm mainly includes three main steps: color space decomposition, tone mapping based brightness adjustment, image synthesis between the brightness and color space. A large number of experiments show that the proposed algorithm can effectively remove the impact of illumination and enhance image quality.

The rest paper is organized as follows. We present our illumination correction algorithm in Section Ⅱ. In Section Ⅲ, the experiments and discussion of this method to plenty of images is introduced, finally, we conclude with future work in Section Ⅳ.

II. THE PROPOSED ILLUMINATION CORRECTION ALGORITHM

A. Color Space Decomposition

A color space is a method by which we can specify, create and visualize color. As humans, we may define a color by its attributes of brightness, hue and colorfulness. A computer will describe a color stimulus in terms of the excitations of red, green and blue phosphors on the CRT faceplate. A printing press describes a color stimulus in terms of the reflectance and absorbance of cyan, magenta, yellow and black inks on the paper. Such a color is usually specified by using three coordinates, or attributes, which represent its position within a specific color space. These coordinates do not tell us what the color looks like, only where the color is located within a particular color space.

Different color spaces are better for different applications, some equipment has limiting factors that dictate the size and type of color space that can be used. Some color spaces are perceptually linear, i.e. a 10 unit change in stimulus will produce the same change in perception wherever it is applied. Many color spaces, particularly in computer graphics are not

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linear in this way. Some color spaces are intuitive to use, i.e. it is easy for the user to navigate within them and creating desired colors is relatively easy. Finally, some color spaces are device dependent while others are not - i.e. device independent.

In this section, we propose a color space decomposition method for illumination correction. This method includes luminance calculation and a new color space definition.

Firstly, we use the following equation (1) to calculate luminance from RGB values.

$$L = a\times R + b\times G + c\times B \tag{1}$$

where $a = 0.27,\ b = 0.67,\ c = 0.06$.

Then, we define our new color space. We extract the value *R*, *G*, *B* of the original image, and define the new value $R',\ G',\ B'$ as follows:

$$\begin{aligned} R' &= R\cdot\left(\frac{1}{L}\right) \\ G' &= G\cdot\left(\frac{1}{L}\right) \\ B' &= B\cdot\left(\frac{1}{L}\right) \end{aligned} \tag{2}$$

The equation (2) is represented as our new color space decomposition. $R',\ G',\ B'$ are represented as the new color value of the corrected image.

B. Brightness Adjustment

Many images, video capture devices such as digital cameras, camcorders, etc., because the image is formed by the reflection of light, while light in the scene often appear uneven illumination, all these will result in making light colors lighter and dark colors darker at the same time when we acquire images. So, it is very important to adjust image brightness to obtain the better quality image. Tone mapping is a technique used in image processing and computer graphics to map one set of colors to another, often to approximate the appearance of high dynamic range images in a medium that has a more limited dynamic range. In this section, we introduce the tone mapping technology to adjust image brightness.

We first define the model of tone mapping as:

$$\begin{cases} L' = \dfrac{\lg[L\cdot\beta\cdot(\alpha-1)+1]}{\lg\alpha} \\ L = 0.27\times R + 0.67\times G + 0.06\times B \end{cases} \tag{3}$$

Where α is the gain of illumination correction, β is the proportional coefficient of illumination correction. *R*, *G*, *B* is represent as the three primary colors of an image.

The above brightness adjustment may be increase the total contrast of an image by making light colors lighter and dark colors darker at the same time. It does this by setting all color components below a specified lower bound to zero, and all color components above a specified upper bound to the maximum intensity (that is, 255). Color components between the upper and lower bounds are set to a linear ramp of values between 0 and 255. Because the upper bound must be greater than the lower bound, the lower bound must be between 0 and 254, and the upper bound must be between 1 and 255. Therefore, for these extreme cases, we need to do the following treatment:

To low lightness processing, we use the following equation to brighten the darker color:

$$\begin{aligned} I' &= \frac{\lg\left(\dfrac{L}{L_{\max}}(\alpha-1)+1\right)}{\lg(\alpha)}\cdot 255 \\ &= \log_\alpha\left(\frac{L}{L_{\max}}(\alpha-1)+1\right)\cdot 255 \end{aligned} \tag{4}$$

where $L_{\max} = 255$.

To high lightness processing, we use the following equation to suppress the lighter color:

$$L' = \frac{\alpha^{\frac{L}{255}}-1}{\alpha-1}\cdot L_{\max} \tag{5}$$

where $L_{\max} = 255$.

C. Image Synthesis

After adjusting brightness, we will combine the brightness adjustment signal with color signals $R',\ G',\ B'$ which obtain at color space decomposition in order to synthesize illumination corrected image signal. This step includes three cases:

Case 1: for the general illumination, the illumination corrected image is as follows:

$$\begin{aligned} R'' &= R'\cdot L' = \frac{R}{L}\cdot L' = \frac{R}{L}\cdot\log_\alpha\left(L\cdot\beta(\alpha-1)+1\right) \\ G'' &= G'\cdot L' = \frac{G}{L}\cdot L' = \frac{G}{L}\cdot\log_\alpha\left(L\cdot\beta(\alpha-1)+1\right) \\ B'' &= B'\cdot L' = \frac{B}{L}\cdot L' = \frac{B}{L}\cdot\log_\alpha\left(L\cdot\beta(\alpha-1)+1\right) \end{aligned} \tag{5}$$

Case 2: for the low illumination, the illumination corrected image is as follows:

$$\begin{aligned} R'' &= R'\cdot L' = \frac{R}{L}\cdot L' = \frac{R}{L}\cdot\log_\alpha\left(\frac{L}{255}(\alpha-1)+1\right)\cdot 255 \\ G'' &= G'\cdot L' = \frac{G}{L}\cdot L' = \frac{G}{L}\cdot\log_\alpha\left(\frac{L}{255}(\alpha-1)+1\right)\cdot 255 \\ B'' &= B'\cdot L' = \frac{B}{L}\cdot L' = \frac{B}{L}\cdot\log_\alpha\left(\frac{L}{255}(\alpha-1)+1\right)\cdot 255 \end{aligned} \tag{6}$$

Case 3: for the high illumination, the illumination corrected image is as follows:

$$\begin{aligned} R'' &= R'\cdot L' = \frac{R}{L}\cdot L' = \frac{R}{L}\cdot\frac{\alpha^{\frac{L}{255}}-1}{\alpha-1}\cdot 255 \\ G'' &= G'\cdot L' = \frac{G}{L}\cdot L' = \frac{G}{L}\cdot\frac{\alpha^{\frac{L}{255}}-1}{\alpha-1}\cdot 255 \\ B'' &= B'\cdot L' = \frac{B}{L}\cdot L' = \frac{B}{L}\cdot\frac{\alpha^{\frac{L}{255}}-1}{\alpha-1}\cdot 255 \end{aligned} \tag{7}$$

III. EXPERIMENTS AND DISCUSSION

Our experiments include two steps. Firstly, we compare our illumination correction algorithm based on tone mapping with histogram equalization and homomorphic filtering. Then, we apply our algorithm to many different images in order to prove the effectiveness of our algorithm.

A. Comparisons

For comparison purpose, we apply three algorithms: histogram equalization, homomorphic filtering and our proposed algorithm, to two color images, respectively. The simulation results are shown in Fig.1 to Fig.2, where (a) are the original images, (b) corrected images by histogram equalization, (c) corrected images by homomorphic filtering and (d) are our corrected images. From these images, we can see that the three methods can both enhance images from poor quality images efficiently, but our results compare favorably to those obtained by the former algorithms.

(a) Original image (b) Corrected image by histogram equalization

(c) Corrected images by homomorphic filtering (d) Our corrected image

Fig.1 Results of different images by different methods

(a) Original image (b) Corrected image by histogram equalization

(c) Corrected images by homomorphic filtering (d) Our corrected image

Fig.2 Results of different images by different methods

B. Applications

We applied our proposed algorithm to handle different poor quality images, including require image under lower illumination and darker illumination. As shown in Fig.3 to Fig.4, (a) are the original images (lower illumination, darker illumination, lighter illumination), (b) are corrected images by our algorithm. From these images, we can see that our proposed algorithm can effectively remove the impact of illumination and enhance image quality.

(a) Original image (b) Corrected image

Fig.3 Image enhancement result of lower illumination

(a) Original image (b) Corrected image

Fig.4 Image enhancement result of darker illumination

IV. CONCLUSIONS

Recently, the problem of illumination correction of images enjoys much attention; its applications span a wide gamut, ranging from improving visual quality of photographs acquired with poor illumination to medical imaging. In this paper, we proposed an image illumination correction algorithm based on tone mapping. The proposed algorithm combined color space decomposition and image brightness adjustment, which can improve the image contrast while maintaining the better color of the original image, and cannot increase noise. On the other hand, this algorithm is based on the pixel processing and does not need image transformation and image statistics information, which can reduce the computational complexity and more easily implement in hardware. Finally, a large number of experiments show that the proposed algorithm can effectively remove the impact of illumination and enhance image quality.

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