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Improving Edge Based Color Constancy for Multiple Light Sources

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Abstract: ***Color constancy algorithms are used for making illuminant independent images. Illuminant independency is achieved in most of algorithms by uniform light source assumption. But this condition may violate in most of real world images which introduces performance failure in computer vision applications like object tracking and object recognition. Local color correction for up to two light sources has been developed by various algorithms. In this paper derivative structure of images are used for local color correction for up to three light sources. Specular edge weighting scheme on derivative structure of image is applied to grid sampled patches of the image to achieve local color correction. Each estimate from patches is combined and result is projected onto input image so that pixel estimate is obtained. Color correction is achieved on a diagonal model with pixel estimates. Experiments show that specular edge weighting method reduces the error when compared with existing local correction methods which uses derivative image structures.***

Keywords: Color constancy, Illuminant, Specular edges

1. Introduction

None of the objects in the universe have color. The color seen by human eyes for an object is the result of reflectance. Color of an object depends on light energy strikes on the object. So the images taken of an object may differ in color if they are taken in different light shining. In various application of computer vision like object tracking, object recognition and surveillance object color have notable importance. As a result of illuminant changing the image color varies. This will cause false result in computer vision applications.

To make constant color for the image of an object, color constancy algorithms are used. The color constancy aim in removing the variant color effects occurred due to different light source environment. One way of make color constant image is to find out invariant features and another way of achieving color constancy is to transform image into a standard form before applying to computer vision applications. This second method is called white balancing, which means removing color of the striking light from the image. Different color constancy algorithms have been developed over the years to estimate color of light source. White patch retinex [6] is the first color constancy method which is based on the assumption that light source color varies smoothly in an image and there is no sharp transition of light source color in adjacent pixels. Light source color obtained from white patch retinex method is the color of most bright patch in the image itself.

Figure 1: Images with two light source effect, taken from web

Another color constancy algorithm named grey world [7] estimates the color of light source by taking the average color of the pixels in an image. This algorithm has a better result than retinex theory. The reason is that it considers the color value of whole image rather than a single patch in the case of white patch retinex. Methods which uses the information obtained from the learning phase is also exit. Gammut constrained algorithm [4] is an example for such method. In this a map is created for map the transferred gamut to a canonical gamut. Gamut means a group of colors possible for a specific light source. Gamut method may fail due to specular highlights in an image under varying illumination so another algorithm [8] is developed to avoid specular highlights by normalizing RGB color vectors. This new method of gamut uses previous gamut algorithm and apply it on 2D instead of 3D. Finlayson and Barnard propose a color by correlation technique [13] which correlates the original image color into a possible set of illuminants. This entire color constancy methods works on pure images. T.Gevers and A. Gijsenij [3] introduced a new color constancy method which works on derivative of images named as grey edge hypothesis. This method uses derivative structure of the images to calculate illuminant value. This work on the assumption that edges in an image contains more variant information so the color value at the edges may give better result than any other portion in an image. Different higher order grey edge hypothesis can be possible depending on level of differentiation used. The drawback of all these colour constancy techniques is they are working on the assumption that the illuminant light source is uniform on the image. But this supposition may violate on most of the images. The reason is that most of the images contain two or more light illuminants. More errors in the results may occur due to single light source assumption.

One of the examples for images contains two or more light sources are images taken under sunlight. This type of images contains regions with sunlight as light source and shadow regions where the presence of sunlight is less when compared with other regions. In order to consider the effect of two or more light sources T. Gevers and A. Gijsenij [1] proposed a new algorithm which uses the already defined previous color constancy methods in a different way. In this paper they presented a local correction of color of images rather than the global correction used previously. This method can be applicable up to images contain two illuminants. They used different sampling methods before applying color constancy to images. Among the sampling method grid sampling is the better one.

In this paper a combination of grid sampling and specular edge weighting of grey edge hypothesis is used to color correction up to three light sources. Photometric edge weighting scheme is used to improve color constancy by the use of different edges in an image. In grid sampling image is divided into small patches. Then edge weighting color constancy scheme is applied to each patches to calculate illuminant value from each patches. Combination of results from each patch is done to reduce errors. Pixel wise illuminant estimate is obtained by back projection. Finally when get pixel wise illuminant estimation von Kries diagonal model [13] is used to correct the color of image.

2. What is Color Constancy?

Color constancy is the ability to recognize the color of object irrespective of the color of light source illuminating the scene. The way of acquiring color constancy is briefly explained below.

2.1 Image color

Image color is the combination of three factors. They are: (1) color light source affecting the scene, (2) reflectance of object surface, and (3) camera sensor response. The image of same object taken by the same camera under different light source environment may vary in color values due to the variation of illuminant values. We can represent the color of an image by

$$E_k = \int_\omega e(\lambda)s(\lambda)c(\lambda)d\lambda \qquad (1)$$

where E_k is the color of image, k∊{R,G,B} and ω represent the visible spectrum. The notations $e(\lambda), s(\lambda), c(\lambda)$ stand for illuminant spectrum distribution, surface reflectance of object and camera sensor response respectively. By taking assumptions on surface reflectance the illuminant value together with camera response can be finding out by color constancy methods.

$$e = \begin{pmatrix} R_e \\ G_e \\ B_e \end{pmatrix} = \int_\omega e(\lambda)c(\lambda)d\lambda \qquad (2)$$

Equation (2) shows the estimate of illuminant together with camera sensitivity. By this estimation of light source we can create a new image which is independent from the light source effect. But most of the color constancy algorithms work on the uniform illuminant assumption. So only a single illuminant estimate is obtained even though there are two or more light sources.

2.2 Color constancy: Single light source effect

Most of methods for color constancy work on the principle that three will be only a single light for shining the entire scene. For example, maximum response patch is selected for color correction in white watch retinex [6] whereas in grey world theory [7] mean of the image pixel values are used for color correction. All the other method is also using this type of assumptions to calculate the single color value for the illuminating light source. By using this single estimate per image, color correction of entire image is done globally. Let us see how to obtain the general framework for global correction of images used in most of the color constancy methods.

First of all integrate the surface reflectance over the entire image.

$$\frac{\int s(\lambda,x)dx}{\int dx} = g(\lambda) = G \qquad (3)$$

The value of G is between one for full reflectance (white) and zero for no reflectance (black). For obtaining better results assume full reflectance, that is take value of G as one. Then find out the average image color by integrating the color of image.

$$\frac{\int E_k(x)dx}{\int dx} = \frac{1}{\int dx}\int\int_\omega e(\lambda)s(\lambda,x)c(\lambda)d\lambda dx \qquad (4)$$

$$= \int_\omega e(\lambda)c(\lambda)\left(\frac{\int s(\lambda,x)dx}{\int dx}\right)d\lambda \qquad (5)$$

$$= G\int_\omega e(\lambda)c(\lambda)d\lambda = Ge_k \qquad (6)$$

Averaging (6) with Minkowski norm p and smoothen it by using a Gaussian filter with standard deviation σ gives general equation for about five different color constancy instantiations.

$$\left[\int\left|\frac{\partial^n E_{k,\sigma}(x)}{\partial x}\right|^p dx\right]^{\frac{1}{p}} = Ge_k^{n,p,\sigma} \qquad (7)$$

where n is the order of differentiation, k∊{R, G, B} and $e_k^{n,p,\sigma}$ is used to show various forms of color constancy methods. By varying the parameters n,p,σ different algorithms can be formed.

- White patch retinex: Minkwoski norm p=∞,n=0 and smoothening filter standard deviation σ=0, i.e., $e_k^{0,\infty,0}$.
- Grey world: Minkwoski norm p=1,n=0 and smoothening filter standard deviation σ=0, i.e., $e_k^{0,1,0}$.

• General Grey World: Minkwoski norm p=8,n=0 and smoothening filter standard deviation σ=1, i.e., $e_k^{0,8,1}$.

• Grey edge hypothesis: Minkwoski norm p=1,n=1 and smoothening filter standard deviation σ=1, i.e., $e_k^{1,1,1}$. And higher order grey edge methods are possible by teking n=2,3,etc..

2.3 Color constancy: Multiple light source effect

Recently T.Gevers and A.Gijsenij [1] proposed a method for finding two estimations of illuminant value from an image. In this new method they applied previously described algorithms into the sampled small patches of the image. Grid sampling, key point sampling and segmentation sampling are the three different sampling strategies used in this method. Among this three methods grid sampling is best because it covers entire image without loss of information from the image. Thus small patches formed after sampling is used for estimation of light source color. Single estimate per patch is obtained after using any of the previously defined algorithms. Then these values are combined to form two groups of estimation values. Average from each group is selected as the corresponding two illuminant value of image. These two estimates are back projected onto the image to find out pixel wise estimation. This method and the methods with uniform light source assumption uses von Kries [13] model for color correction.

2.4 Color correction

The image under an unknown light effect is converted into a standard form by using the estimated value of light source. For this von Kries diagonal model is used.

$$E^C = \wedge^{U,C} E^U \qquad (8)$$

where E^C is the image under canonical light source, E^U is the input image ie. Image under unknown light source and $\wedge^{U,C}$ is the diagonal model used for mapping. Diagonal model can be simply represented as

$$\wedge^{U,C} = \begin{pmatrix} \frac{e_R^c}{e_R^u} & 0 & 0 \\ 0 & \frac{e_G^c}{e_G^u} & 0 \\ 0 & 0 & \frac{e_B^c}{e_B^c} \end{pmatrix} \qquad (9)$$

where e^c and e^U are illuminant value for standard light and unknown light in the input image respectively.

3. Edge based color correction up to three light sources

This new method applies first order grey edge, second order grey edge and new specular edge weighting into sampled small patches to get single estimate from each patch.

3.1 Grid sampling

The input image is divided into equal sized small sections called patches. First of all row wise division is done then column wise division is done. Main advantage of grid sampling over other sampling methods like key point sampling and segmentation sampling is it covers the entire image and no information loss. Different sizing of patches can be done. But various results show that small patch size shows less error. But the problem with very small patch size is it will take large time for evaluating estimation algorithms over each patches. So a medium level patch size is selected.

3.2 Estimation methods

Previously described first order and second order grey edge hypothesis is applied to each patch. New specular edge weighting scheme is described here. There are various types of edges in an image such as shadow, material and specular edges. Material edge is the edge between an object and its background whereas shadow or geometry edge means edge between two different surface geometries. Specular edge is the edge that differentiates two light sources. In this paper specular edges are considered for weighting scheme.

A weighting scheme is applied on the derivative of images so that the specular edge effect can be used for illuminant estimation

$$\left[\int \left|\frac{v(E)^{k1}\partial^n E_{k,\sigma}(x)}{\partial x}\right|^p dx\right]^{\frac{1}{p}} = Ge_k^{n,p,\sigma} \qquad (10)$$

$(E)^{k1}$ is the weight which is assigned to every value of E and k1 is used to impose the effect of weight on edges. Weight can be computed from the specular variant. The projection of image derivative on light source color is called as specular variant which shows the energy of derivative among specular edge direction.

$$O_x = (E_x . \hat{c}^i)\hat{c}^i \qquad (11)$$

where E_x is the derivative of image and $\hat{c}^i$ is the light source color which is assumed as white light source initially. The specular edge weight is calculated as ratio of specular variant and derivative of image.

$$v(E_x) = \frac{|O_x|}{||E_x||} \qquad (12)$$

3.3 Merging of estimates

Single value of color from each patch is obtained from previous color estimation step. From these estimation three groups of color estimation is formed. Average of each group is considered as value of each three light sources

3.4 Pixel wise illuminant estimation

The three illuminant values from edge weighting scheme are projected into full image and find which illuminant is affecting each pixel. But the problem is lying with the images which have no sharp distinction between two light sources. There will a chance for detecting false illuminant estimate for a pixel within a patch if the patch is distributed with two light sources. To overcome this mask is created. Chromatic distance $cd_j(x)$, between the estimated light source of the patch located at position x is and the other illuminant is find out. From this the similarity between estimated light source color and other is computed as $cd'_j(x)$.

$$cd_j'(x) = \frac{\sum_x \mathrm{cd}_j(\mathrm{x})}{\mathrm{cd}_j(\mathrm{x})} \quad (13)$$

A mask is created to define the probability of estimated light source.

$$m_j(x) = \frac{cd_j'(x)}{\mathrm{cd}_1(\mathrm{x}) + \mathrm{cd}_2(\mathrm{x}) + \mathrm{cd}_3(\mathrm{x})} \quad (14)$$

This mask is used for calculating pixel wise estimation.

$$e_p(x) = e_{p,1}m_1(x) + e_{p,2}m_2(x) + e_{p,3}m_3(x) \quad (15)$$

where $e_p(x)$ is the pixel wise estimation over the entire scene, $e_{p,1}$, $e_{p,2}$ and $e_{p,3}$are first ,second and third light source estimates respectively and $m_1(x)$, $m_2(x)$ and $m_3(x)$ are mask created for each light sources.

3.5 Color Correction

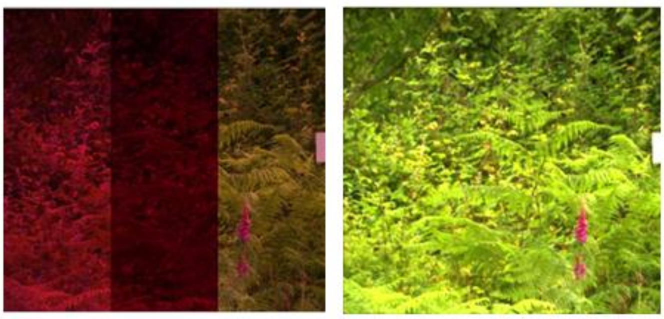
Main aim of this step is to convert all images into a form such that it was taken under a white light background. So that a standard form for evaluating the color of image can be formed. Here the input image is multiplied with the von Kries diagonal model [13] which is created from the pixel color estimates.

4. Performance measurement

For evaluating the performance of this new method for local color correction of images the standard median angular error is taken as the criteria. The estimated light source value e_p and original color value of the light source e_l is taken to calculate angular error of the proposed method.

$$\text{Angular error} = \cos^{-1}(\hat{e}_p \cdot \hat{e}_l) \quad (18)$$

Normalized vectors of values are used here which is shown by (^) sign. Pixel by pixel angular error is calculated throughout the image and an average of this is taken as measurement.



(a) (b)

Figure 2: (a) Input Image (b) Color corrected Image

Table 1: Performance measurement of Different edge based color constancy methods

Method (**Color Correction Of Three Light Sources**)	**Median angular error**
First order grey edge	11.48º
Second order grey edge	11.44º
Specular edge weighting	8.5º

Experiments are done on a dataset of eight images illuminated by three different light sources randomly selected from a set of 94 illuminant spectra. By this 752 images are created and proposed methodology is applied on the images.. Median angular error is taken as the parameter for performance measurement. Proposed methodology of combiantion along with first order grey edge and second order grey edge is performed on given dataset and compared the result with specular edge weighting for three light sources on the same dataset. Results are shown in table1. Results shows an improvement of edge based color constancy for threee light sources by specular edge weighting. Finally the result of proposed algorithm on image from dataset is shown in figure 2.

5. Conclusion

Edge weighting improves the performance of grey edge hypothesis for local color correction. Specular edges have the property that they differentiate the light sources there by proposed methodology of grid sampling with specular edge weighting for local color correction outperforms the grey edge hypothesis. This method can also be used for scenes with uniform illumination. Main drawback of this hypothesis is slow response since it works on an iterative algorithm it will take more time. But in the scenes with more edges this method gives better results than any other methods. As a future work other edge types can also be included in edge weighting.

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