A Literature Review of Various Color Constancy Techniques in Digital Image Processing

[1]Buta Singh, [2]Ashok Kumar Bathla
[1,2]YCOE, Talwandi Sabo, India

Abstract
This paper presents an overview of various color constancy techniques. Color constancy is the ability to estimate the color of the light source. Different illuminants may impact the appearance of an image as compared to the image taken under canonical light source. Human vision has the natural tendency to estimate the color of light source but this mechanism is not fully understood. So, This paper presents various computational methods to estimate the effect of color of different light sources onto a digital image. This paper presents a survey of various color constancy techniques under different illumination conditions. Experimental and visual results show the comparative performance analysis of various color constancy techniques.

Keywords
Color Constancy, Illumination, Computer Vision

I. Introduction

Color constancy is the ability to recognize colors of objects independent of any cue about the color of the light source. Color can be an important cue for many computer vision applications like human computer interaction, color feature extraction and color appearance models. Changes in illuminants cause the measurement of object colors to be biased towards the color of the light source. Human vision system has the ability to recognize the colors of the light source to some extent but perceive the same color of an object despite large differences in illumination. Hence, various computational color constancy algorithms have been developed for recent overviews. The criteria for color constancy using various computational models focus on following facts:-

- The requirement of training data set.
- The accuracy of the estimation.
- The effectiveness of the computational model used.
- The computational run time of the method.
- Transparency of the approach.
- Number of parametric proofs.

II. Color Constancy

Color constancy can be achieved by estimating the color of the light source, followed by a transformation of the original image values using the illuminantion estimation. The image values f for a Lambertian surfacedepends on the color of the light source e(λ), the surface reflectance S(x,λ) and the camera sensitivity function C(λ).

$$F(x) = \int_W e(\lambda)\, C(\lambda)\, S(x,\lambda)\, d\lambda$$

Where w is the visible spectrum, λ is the wavelength of the light and x is the spatial coordinate. Since, both e(λ) and C(λ) are in general unknown. This is an under constrained problem. Therefore, color constancy is needed to solve this problem using further assumptions.

A. Illuminant Estimation Under One Light Source

Many color constancy algorithms are developed so far during research study in color constancy but they all are based on estimation of single uniform source of light onto a digital image. Algorithm like white patch algorithm , Grey World algorithm and gamut mapping based algorithm are based on the assumption of single uniform source of light. Recent research comes into existence regarding estimation multiple sources of light as discussed below.

B. Illuminant Estimation Under Multiple Light Sources

The majority of color constancy algorithm is based on one light source i.e. they are based on the assumption of spectrally uniform lighting. However, in real world, an image may be affected by different multiple sources of light. The Grey edge algorithm and Physics based algorithms are based on estimation of color of multiple sources of light. Hence, better results can be produced by considering multiple sources of light as a color constancy mechanism.

C. Image Correction Model

Since the main goal of color constancy algorithms is to estimate the color of light sources that affected a digital image as compared to, the same image taken under a canonical light source. After light estimation, image correction mechanism is applied to obtain standard output image. Diagonal Model called Von Kries Model is used to correct the image as discussed in recent research study. After the color of the light source is estimated to transform the input image, taken under an unknown light source , into colors as if they appear under a canonical light source . Usually, this is done using the diagonal model or Von Kries model.

III. Color Constancy Approaches

As discussed above, Color constancy is based on following two approaches which are further categorized into different color constancy techniques i.e.-

- Pixel Based Approach.
- Edge Based Approach.

A. Pixel Based Color Constancy

Pixel Based color constancy algorithm focuses on the estimation of illuminant using only the pixel values in an image. These algorithms process all the pixel values of an image to estimate the light source. Pixel based color constancy algorithms are divided into following three categories:-

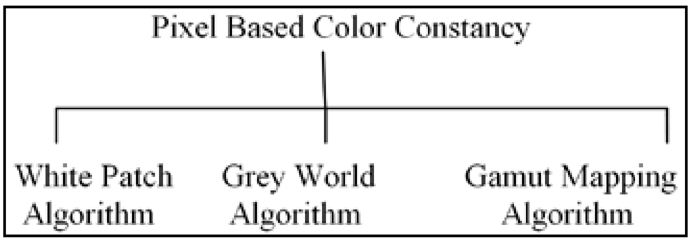
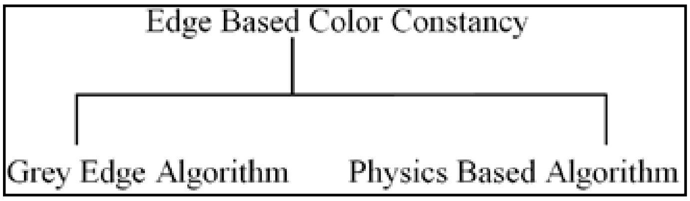


Fig. 1:

B. Edge Based Color Constancy

Recently, Pixel based method is extended to edge based color constancy algorithms, Since most of the details in an image is represented by its edges. Various image derivatives (i.e. edges) are calculated for estimation of color of light source. Two well known edge based color constancy algorithms are:-



IV. Color Constancy Techniques

A. Retinex Based White Patch Algorithm

Retinex is one of the first color constancy method developed and it considers that an abrupt change in chromaticity is caused by a change in reflectance model. This implies that the illuminant smoothly varies across the image and does not change between adjacent or nearby locations. Various implementations have been proposed using this theory. The white patch algorithm is also a retinex theory based algorithm which works on white patch assumption i.e. the assumption that the maximum response in RGB channels is caused by a white patch. However, all these methods are based on the assumption that the illuminant transition is smooth, which is not the case. Hence, Retinex theory was a fundamental step towards color constancy based on one light source.

B. Grey World Algorithm

The second algorithm, the grey world algorithm is based on grey world assumption i.e. the average reflectance in the scene is achromatic. The light source color can now be estimated by computing the average pixel value which yields the normalized light source color. This is indeed a very simple algorithm to find the light source color of a scene. Since, the grey world algoritm is sensitive to large uniformaly colored surfaces. Related methods may attempt to identify the intrinsic grey surfaces in an image i.e. they may attempt to find the surface under a colored light source that would appear grey if rendered under a white light source. Further improvements may provide better results in grey world algorithm [8].

C. Gamut Mapping Algorithm

The gamut mapping is introduced by Forsyth in 1990. Gamut mapping algorithm is also based on Pixel based color constancy approach. It is based on the assumption of human vision system. Since, one can observe only a limited number of colors for a given light source in real world images. But, any variations in the colors of an image i.e. the colors that are different from the colors that can be observed under a given illuminant are caused by variation in the color of light source. The limited set of colors under a given illuminant is represented as a canonical gamut C which is computed under a given light source by observing many surfaces.

The flow of gamut mapping is as follows:-

- Compute the gamut of unknown light source. The colors of the input image help in estimating the gamut of unknown light source.
- Determine the set of feasible mappings M i.e. all mappings that are applied in an input image should lies within canonical gamut C i.e.

$M_i I \in C$

Where, I is an input image.

- Select one mapping from a set of feasible mappings by using an estimator. The selected mapping can be applied to canonical mapping to estimate the unknown light source.

Another extension of gamut mapping algorithm deals with dependency on diagonal model. But, this approach has a problem i.e. if the diagonal model fails, no feasible mapping can be found that maps the input image data into the canonical gamut [5].

All these variations of gamut mapping algorithm are restricted to the use of pixel values to estimate the illuminant and works only on one uniform light source. Further improvements are needed to make the results better as discussed below [1].

D. Grey Edge Algorithm

Most of the methods developed in past research are based on single uniform source of light and they consider the pixel values to estimate the source of light, which is not the case always. Since, an image can also be affected by multiple sources of light. Hence, in this paper a new method called grey edge is presented that enables color constancy under multiple light sources. Recently, pixel based methods are extended to incorporate derivative information (i.e. edges) and high order statistics, resulting in grey edge algorithm. This algorithm is designed to create the edge based color constancy since most of the details are presented by the edges of an image. Since, the grey world algorithm is based on the assumption that the average reflectance of surfaces in the world is achromatic. The grey edge algorithm is based on the assumption that the average edge difference in a scene is achromatic. With the grey edge algorithm assumption the light source color can be computed from the average color derivative in the image. Results are comparable to more elaborate algorithms, however, at lower computational cost and less complexity and lower computational run time [8].

E. Physics Based Algorithm

Physics based algorithm is also based on edge based color constancy approach. Other algorithms that consider multiple sources of light, include physics based methods requiring manual intervention. Physics based methods make use of image derivatives to estimate the color of light source. Since the edges play an important role in estimating the color of light source, physics based method also based on the assumption of calculation of different edge types in real world images i.e. shadow, geometry material and highlight edges. After identifying edges, grey edge algorithm is applied to estimate the color of light source. In this algorithm, first an edge based taxonomy is presented classifying edge types based on their reflectance properties (e.g. material, shadow geometry and highlights). After this, an edge based performance evaluation is provided using different edge types. From this evaluation, it is derived that certain edge types are more valuable than material edges for the estimation of illuminant. As discussed above, at the end, a grey edge algorithm is proposed in which these valuable edges are processed for the estimation of illuminant. Physics based method provides better result than grey edge algorithm [9].

V. Related Work

In 1977, E Land et al. [1] has studied a traditional scheme for color constancy which is based on retinex theory. Land et al. Has studied that an abrupt change in chromaticity is caused by a chnge in reflectance model. Although retinex theory is an old technology but it has helped in many recent color constancy techniques to provide efficient results.

In 2002, Barnard et al. [2] has discussed about a number of computational color constancy algorithms on the basis of synthesized data. This paper also provides a comparative study of various color constancy algorithms, based on well known experimental results and different data set images. The work in this paper has laid the foundation for future work with image data. Barnard et al. have developed a comprehensive understanding on how a number of the leading algorithms perform in controlled circumstances, and we are therefore in an excellent position to interpret results from image data obtained with complementary methodology.

In 2005, Weijier et al. [3] has proposed a grey edge based color constancy algorithm which assumes the average edge difference in a scene to be achromatic. Further, an extension based on the Minkowski norm is proposed. The algorithm provides better results on a large data set.

In 2007, Weijer et al. [4] has presented an edge based color constancy algorithm as an extension to traditional algorithms. Since most of the details are presented by edges of the image, hence, edge based color constancy provides better results than grey world and retinex theory algorithms.

In 2010, Gijsenij et al. [5] has studied generalized gamut mapping color constancy algorithm based on image derivative structures. This is the most promising method to achieve computational color constancy.However, so far, gamut mapping algorithms are restricted to the use of pixel values to estimate the illuminant. Therefore, in this paper, gamut mapping is extended to incorporate the statistical nature of images. Gijsenij et al. also discussed a survey and experiments of various color constancy algorithms. [6]. Several criteria are proposed that are used to assess the approaches. A taxonomyof existing algorithms is proposed and methods are separated in three groups: static methods, gamut-based methods and learning-based methods. Finally, various freely available methods, of which some are considered to be state-of-the-art, are evaluated on two data sets.

In 2011, Gijsenij et al. [7] has discussed a color constancy approach based on semantics and statistics of natural images. To achieve selection and combining of color constancy algorithms, in this paper natural image statistics are used to identify the most important characteristics of color images. Then, based on these image characteristics, the proper color constancy algorithm (or best combination of algorithms) is selected for a specific image. Experimental results show a large improvement over state-of-the-art single algorithms, on a data set consisting of more than 11,000 images, an increase in color constancy performance up to 20 percent.

In 2012, Gijsenij et al. [8] has proposed a new technique for color constancy based on multiple light sources. Techniques developed so for, has an obvious disadvantage that they all are based on single uniform light source, which is always not true. Since, an image may be affected by different sources of light, hence multiple sources of light are considered to estimate the color of the light source. Experimental and visual results show the superiority of this technique over conventional techniques.

VI. Comparative Study

Author(s)	Year	Paper Name	Technique	Light Source	Results
D. Forsyth.	1990	A Novel Algorithm for Color Constancy	Gamut Based Algorithm	Single	Find the impact of color of light source.
Barnard et al.	2002	A Comparison of Computational Color Constancy Algorithms	Different types of Color constancy Algorithms like grey world, color by correlation	Single	Comparative Analysis of different algorithms
Gijsenij et al.	2007	Edge Based Color Constancy	Grey World Algorithm and Grey Edge Algorithm	Single for Grey World Algo. And Multiple for Grey Edge	Better results are produced by grey edge.
Arjan Gijsenij et al.	2010	Computational Color Constancy- Survey and Experiments	Physics Based method and Gamut Based Method	Single for Gamut method and Multiple for Physics method.	Gamut method provides high accuracy
Gijsenij et al.	2011	Color Constancy using Natural Image Statistics and Scene Semantics	Natural Image Statistics	Multiple	Weibull parameterization helps in identifying the most important Characteristics of color images
Gijsenij et al.	2012	Color Constancy for Multiple Light Sources	Patch Based Illumination Estimation	Multiple	Provides very efficient results by considering Multiple Sources of Light

VII. Conclusion and Future Work

To conclude, various methods are discussed in this paper. No method is considered as universal. However, with the survey of large variety of available methods, the question is how to select a method that performs best for a specific image. Existing methods presented in this paper can be extended to more realistic scenarios where the uniform light source is too restrictive and more robust methods i.e. which consider multiple sources of light, needs to be developed as a future research work for color constancy.

Refrences

[1] E.Land,"The Retinex Theory of Color Vision", Scientific American, 1977.

[2] Kobus Barnard, Vlad Cardei, Brian Funt,"A Comparison of Computational Color Constancy Algorithms—Part I: Methodology and Experiments With Synthesized Data", IEEE Transactions on Image Processing, Vol. 11, No. 9, September 2002.

[3] J. Van de Weijer, Th. Gevers,"Color Constancy Based on Grey Edge Hypothesis", IEEE 2005.

[4] Weijer et al.,"Edge Based Color Constancy", IEEE Transactions on Image Processing, Vol. 16, No. 9, September 2007.

[5] Arjan Gijsenij, Theo Gevers, Joost van deWeijer "Generalized Gamut Mapping using Image Derivative Structures for Color Constancy", Springer, Int J Comput .Vision, 2010.

[6] Arjan Gijsenij, Theo Gevers, Joost van de Weijer "Computational Color Constancy: Survey and Experiments", IEEE Transactions on Image Processing, Vol. 10, No. 10, Month 2010.

[7] Arjan Gijsenij, Theo Gevers,"Color Constancy Using Natural Image Statistics and Scene Semantics" , IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 33, No. 4, April 2011.

[8] Gijsenij et al.,"Color Constancy for Multiple Light sources", IEEE Transactions on Image Processing, Vol. 21, No. 2, Feb. 2012.

[9] Gijsenij et al.,"Physics Based Edge Evaluation for Improved Color Constancy".

Buta Singh received his B.Tech degree in computer engineering from College of Engineering & Management Punjabi University Neighbourhood Campus Rampura Phul (Bathinda) under Punjabi University Patiala in 2011 and pursuing M Tech.(Regular) degree in computer engineering from Yadavindra College of Engineering Punjabi University Guru Kashi Campus Talwandi Sabo (Bathinda), batch 2011-2013. His research interests include digital image processing. At present he has guided many students regarding the research study in digital image processing.