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A Review on Color Constancy Algorithms

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Abstract- This paper presents detailed study of various color constancy techniques. Color constancy is the ability to estimate the color of the light source. Different illuminates 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 work presents various computational methods to estimate the effect of color of different light sources onto a digital image. This work has presented a comparative study of available research.

Index Term- **Color Constancy, Illumination, Computer Vision.**

I. INTRODUCTION

The color of a light source has a significant influence on object colors in the scene. Therefore the same object, taken by the same camera but under different illumination, may vary in its measured color values. This color variation may introduce undesirable effects in digital images. Moreover it may negatively affect the performance of computer vision methods for different applications such as object recognition, tracking and surveillance. The aim of color constancy is to correct for the effect of the illuminant color, either by computing invariant features or by transforming the input image such that the effects of the color of the light source are removed. Color constancy is the ability to recognize colors of objects independent of the color of the light source. Obtaining color constancy is of importance for many computer vision applications, such as image retrieval, image classification. Approaches to this problem can be divided into two groups. For the first group, the aim is to represent images by features which are invariant with respect to the light source, for example within the context of image retrieval. For these methods the actual estimation of the light source is not necessary. For the second group of approaches, the aim is to correct images for deviations from a canonical light source. Contrary to methods in the first group, solutions to this problem do estimate the color of the light source, be it explicitly or implicitly. Methods, either propose light source estimation, [8] after which the image is corrected, or they directly estimate the color corrected image, after which the light source can be derived. If desired, illuminant invariant features can subsequently be derived from the corrected image. We look at color constancy approaches of the second group, i.e. methods from which a light source corrected image can be computed. The [4] method is based on the observation that only a limited set of RGB values can be observed under a given illuminant. The set of all possible RGB values for the canonical illuminant, typically a white illuminant, is called the canonical gamut. This canonical gamut is proven to be a convex hull in RGB space. The algorithm computes what transformations map an observed gamut into the canonical gamut. From these transformations, the illuminant color is derived. Although the above described algorithms arrive at reasonable color constancy accuracy, a drawback is that they are based on complex algorithms and all require an image data set with known light sources for calibration. In this paper, we will focus on color constancy based on less complex color constancy algorithms. To this end, fast algorithms are considered which are based on low-level image features, such as max-RGB and Grey-World. Max-RGB is a simple and fast color constancy algorithm which estimates the light source color from the maximum response of the different color channels. Another well-known simple color constancy method is based on the Grey-World hypothesis, which assumes that the average reflectance in the scene is achromatic. These low-level methods are widely in use, even in digital consumer cameras, due to their very low computational costs, i.e. taking the maximum (max-RGB) or average pixel values (Grey-World). A new methodology that can be used to apply color constancy to images that are recorded in the presence of [7] multiple different light sources have been proposed. Most existing algorithms are based on the assumption that the spectral distribution of the light source is uniform across the scene, but this assumption is often violated in reality. We have shown that many existing methods can be locally applied to image patches, rather than globally to the entire image. Interestingly, grid-based sampling outperformed than existing methods. To conclude, the methodology has been shown to be able to extend existing methods to more realistic scenarios where the uniform light-source assumption is too restrictive. We have shown that patch-based illuminant estimation can be as accurate as global illuminant estimation when the light source is (approximately) uniform. Furthermore, when there are two distinct light sources present in an image, the proposed methodology is able to increase the performance of existing algorithms considerably.

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 surface [8] depends on the color of the light source $e(\lambda)$, the surface reflectance $S(x,\lambda)$ and the camera sensitivity function $C(\lambda)$. $F(x) = \int e(\lambda)C(\lambda)S(x,\lambda)\, d\lambda$ Where λ is the wavelength of the light and x is the spatial coordinate. Since, both $e(\lambda)$and $C(\lambda)$ are in general unknown. This is an under constrained problem. Therefore, color

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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, [7] better results can be produced by considering multiple sources of light as a color constancy mechanism.

IV. 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:-

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. COLOUR 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 [1] 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 algorithm 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.

C. Gamut Mapping Algorithm:

The gamut mapping is introduced by Forsyth in 1990. [4] 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:-

(1) Compute the gamut of unknown light source. The colors of the input image help in estimating the gamut of unknown light source.

(2) 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.

$M_i I \in C$

3) 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. All these variations of [4] 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.

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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 [2] 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 [3] comparable to more elaborate algorithms, however, at lower computational cost and less complexity and lower computational run time. Edge detection is not only an important part of image analysis, but also an important pre-processing technology of image processing domain. It has also been widely used in feature extraction and texture profile analysis. Therefore, to find an efficient edge detection method with excellent noise resistance and exact edge location keeps as an object of a prolonged Endeavour. The edges extracted from a two-dimensional image of a three-dimensional scene can be classified as either viewpoint dependent or viewpoint independent. A viewpoint independent edge typically reflects inherent properties of the three-dimensional objects, such as surface markings and surface shape. A viewpoint dependent edge may change as the viewpoint changes, and typically reflects the geometry of the scene, such as objects occluding one another.

V. RELATED WORK

In 2002,Barnard et al. [1] 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. [2] 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. [3] 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. [4] 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. [5].Several criteria are proposed that are used to assess the approaches. Taxonomy of 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. [6] 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. [7] 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. In 2012, Lisa Brown et al. [8] has discussed limitations of color measurement accuracy and discovered how this information can be used to improve the performance of color constancy. The work in this paper has proposed color strength which states that combination of saturation and intensity can calculate consistency of color information exactly.

VI. COMPARATIVE ANALYSIS OF RESEARCH PAPER

Author (s)	Year	Technique
Barnard et al.	2002	Color constancy Algorithms like grey world, color by correlation
Gijsenij et al.	2007	Grey World Algorithm and Grey Edge Algorithm

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ArjanGijsenij et al.	2010	Physics Based method and Gamut Based Method
Gijsenij et al.	2011	Natural Image Statistics
Gijsenij et al.	2012	Patch Based Illumination Estimation
Lisa Brown et al.	2012	Grey world, General Grey World, Grey Edge and Second Order Grey Edge Algorithms

Author (s)	**Light Source**	**Results**
Barnard et al.	Single	Comparative Analysis of different algorithms
Gijsenij et al.	Single And Multiple	Better results are produced by grey edge.
ArjanGijsenij et al.	Single and Multiple	Gamut method provides high accuracy
Gijsenij et al.	Multiple	Weibull parameterization helps in identifying the most important Characteristics of color images
Gijsenij et al.	Multiple	Provides very efficient results by considering Multiple Sources of Light
Lisa Brown et al.	Multiple	Color Strength model along with hue error provides improvement in results of color constancy methods.

VII. CONCLUSION

Color constancy is the capability to determine colors of objects independent of the color of the light source. This paper proposes an integrated approach which combines the edge based color constancy with the nonlinear color enhancement. Edge-based color constancy methods make use of image derivatives to estimate the illuminant. However, different edge types exist in real-world images, such as material, shadow, and highlight edges. These different edge types may have a distinctive influence on the performance of the illuminant estimation. The proposed techniques seems to be correct as when color correction is performed some pixel may become darker or lost due to correction in the color, so proposed techniques will produce better results as it is integrating the edge based color constancy with adaptive image restoration. Color vision is a process by which organisms and machines are able to distinguish objects based on the different wavelengths of light reflected, transmitted, or emitted by that object. In humans light is received by the eye where two types of photoreceptors, cones and rods, send signals to the visual cortex which in turn processes those sensations into a subjective perception of color.

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AUTHOR'S PROFILE

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