

Enhanced 2nd Order Gray Edge Color Constancy Algorithm Using Bilateral Filter

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Abstract: The color constancy techniques becomes an important pre-processing technique which reduces the effect of the light source on the given image or scene. It is found that light effects lot on a given scene. So effect of the light source may degrades the performance of certain applications a lot like face recognition, object detection, lane detection etc. Color constancy has ability to detection of color independent of light source. It is a characteristic of the distinct color awareness organization which guarantees that the apparent color of objects remains relatively constant under altering illumination conditions. The overall goal of this paper is to propose a new algorithm 2nd order gray edge based color constancy algorithm using bilateral algorithm. The overall attention is to enhance the color constancy algorithm further. The histogram stretching is also used to improve the results. The comparison has shown the significant improvement over the available techniques.

Index terms: Color constancy, Light source, light, Edge based color constancy and Gray world.

1. Introduction

The human visual system is able to regulate the color of objects from the spectral power distribution entering the eye. This ability to calculate color constant or approximately color constant descriptors is called color constancy. Even though a number of theories exist, it is not known exactly how the human brain computes color constant descriptors. Color constancy is very significant for many different areas, such as consumer photography or automatic color-based object recognition. Many different algorithms have been planned in order to solve the problem of color constancy. Whereas most color constancy algorithms accept that the objects shown in the image can be modelled as diffuse reflectors, some algorithms also take specular reflections into account, color constancy.

Color Constancy can be defined as ability to recognize colors of objects, invariant to illuminant. This ability is usually endorsed to the Human Visual System, while the accurate details remain uncertain. To illustrate it example is shown in the figure 1.1. In the given example, the same flower is represented four times, under a different source of light. It can be seen, that the flower color is stoutly dependent on the color of the light source.



Figure 1.1: Color constancy under different illumination

Computational Color Constancy follows different ways to maintain color appearance evenly under different light sources. One of the ways, which is believed not to mimic the human visual system, but is considered to be common among computational models. The problem is approached using two phases. First approach is based on number of assumptions; the light source color can be estimated from an input image.

The color of objects is primarily affected [8] by the color of the light source. The related object, taken by the same camera but beneath different light, may vary in its measured color appearance. This color deviation may negatively affect the result of image and video processing methods for different applications such as image segmentation, object recognition and video retrieval. The purpose of color constancy is to eliminate the effect of the color of the light source.

Because existing color constancy algorithms are based on

precise assumptions, none of them can be considered as widespread. A number of color constancy methods have been proposed which take upper level visual information into account. For example, high-level visual information is used for color constancy. The image is shown as a combination of semantic classes, such as sky, grass, road and buildings. Image statistics are used in to get better color constancy. It is shown that images with similar image statistics should be corrected by the identical color constancy algorithms. Also, similar image statistics specify a specific image category (i.e. scenes). For particular instance, the White-Patch color constancy algorithm is appropriate for the forest category while the 1st-order Grey-Edge is appropriate for the street category. Hence, it shows that there is a correlation among image statistics, scene types and color constancy algorithms.

A. Image Correction

The input image can be corrected if the chromaticity of the source light is known. When an input image is converted under an unknown light source, into an output image under a canonical light source, is called adaptation. When certain conditions are met chromatic adaptation can be modelled using a linear transformation, which can be simplified by a diagonal transformation.

Color correction methods are used to compensate for illumination conditions. In human perception such correction is called color constancy-the ability to perceive a relatively constant color for an object even under varying illumination. Most computer methods are pixel-based, correcting an image so that its statistics satisfy assumptions such as the average intensity of the scene under neutral light is achromatic, or that for a given illuminant, there is a limited number of expected colors in a real-world scene. Various schemes have been proposed to use features instead of pixels including higher order derivatives.

Image features are selected based on their probability to best characterize the illuminant color and ignore the specific color of the objects in the scene. For example, higher order derivatives are used based on the assumption that the average of reflectance differences in a scene is achromatic. However, to the best of knowledge, none of the existing methods account for the fact that even at the level of the distinct pixels, the reliability of the color information varies. Introduce the notion of color strength, a measure of color information accuracy.

2. METHODS OF COLOR CONSTANCY

There are three types of methods that are distinguished, from each other with their own advantages and disadvantages.

A. Static Methods

Static methods are applied to images having fixed parameter setting. These can be based either on low-level statistics or on the physics-based dichromatic reflection model. First type of methods includes the Grey-World, the White-Patch and the Grey-Edge methods, integrated in one framework by van de weijer et al.

The grey world algorithm takes an assumption that the average color in a scene is achromatic under a white light source. This means that by the effects of the source light deviation of the average color away from grey is caused. In color space, it can

be defined as the bulk of the image colors of an image under a white light source are aligned with the intensity axis and the bulk of the image colors of an image under arbitrary light source are aligned with the color of the light source.

The White-Patch algorithm assumes that the maximum pixel value is white. This assumption alleviate by considering the color channels separately, which results in the max-RGB algorithm.

The Grey-Edge algorithm is defined as the average edge in a scene is grey. Instead of pixels derivatives of image are used. This method clearly models the spatial dependencies between pixels.

Physics-based methods are the second type of static algorithms. Such methods frequently assume the more general dichromatic reflection model rather than the Lambertian reflectance model. The main difference between the two is the addition of a specular component, which is used to model the reflectance in the viewing direction. These methods use information about the physical interaction between the light source and the objects in a scene. The basic assumption of most methods is that all pixels of one surface fall on a plane in RGB color space. Multiple of such surfaces result in multiple planes, so the intersection between the planes can be used to compute the color of the light source.

B. Gamut Mapping

Gamut mapping is method which is based on the assumption, that for a given illuminant in real-world images, only a limited number of colors are observed. For that reason, deviation in the color of light source leads to unpredicted variation in the colors of an image. The term called canonical gamut is learned from a training set defined as restricted set of colors that occurs under a given illuminant. Trained set contains any number of images. Then input gamut can be constructed for any input image, which can be used as set of colors for the light source to record the input image. Set of mappings can be computed by using the canonical gamut and the input gamut that maps the input gamut totally inside the canonical gamut. Out of the feasible multiple mappings, one of the mappings has to be selected as the estimated illuminant. Finally, output image is constructed by selected mapping is used to construct the output image

C. Learning-based Methods

The learning based algorithms uses a model learned on training the data to estimate the illuminant. Learning techniques feature vector extracted from the input image. None of the color constancy algorithms can be considered as universal with respect to large variety of available methods.

3. Literature review

Color constancy is very significant for many different areas, such as photography or automatic color-based object recognition. Many different algorithms have been proposed in literature to solve the problems of color constancy. Different assumptions are considered. Still it needs to be further explored. The brief literature survey is as follows.

Ebner et al. (2007) [8] had demonstrated that the color constancy is crucial for digital photography and automatic color-based object recognition. There are number of algorithms

developed for color constancy but the author had reviewed two well-known color constancy algorithms. They are the gray world assumption and the Retinex algorithm which showed how a color constancy algorithm can be integrated into the JPEG2000 framework with Local space average color. Local space average color is used as an estimate of the illuminant; it is required to change the LL band of the highest level in order to find a color adjusted image. The method can be used to integrate into decoding devices. Decoding devices could modify the sub-bands at the discretion of the user.

Lu et al. (2009) [12] has demonstrated that the objective of color constancy is to identify the object under the effect of the color of the light source. Although there were various color constancy algorithms available, none of them can be considered universal. The author had proposed a stage model which is 3-D models of a scene can be used to select a proper algorithm for a given image by considering the angular error of the five different color constancy algorithms. An experiment was performed on large scale image dataset which had demonstrated that the proposed color constancy algorithm outperforms state-of-the-art single color constancy algorithms with an improvement of nearly 8%. Ideally, the proposed algorithm can make an improvement of more than 12% over the best single algorithm.

Moreno et al. (2010) [10] has presented an inventive chromatic gradient computation, which was chromatically coherent. It preserved the Color Constancy and gives good detection of Color Edges. It was invariant to intensity magnitude, demonstrating high robustness against bright spots produced and dark regions of low intensity. It worked on the RGB space and does not need color segmentation. In the future this approach can be applied to robust reflectance analysis, which will provide good separation of color regions as the starting point for diffuse and specular component separation.

Choudhury et al. (2010) [1] proposed a new technique for color constancy which was based on the statistics of images with color cast. The method was based on the observation that under colour illumination an image of a scene has one color channel that had significantly different standard deviation from at least one other color channel. The denoising algorithms were used to solve the problem of noise due to which illumination estimation may not be correct. The authors had performed experiments on two generally used datasets. It was shown that the given technique was strong to choice of dataset and had given results that were at least as good as existing color constancy methods.

Bianco et al. (2011) [14] demonstrated that computational color constancy defines that under changing illumination it was used to estimate the actual color in an acquire scene. The author had taken into account classification-based color constancy which was used to automatically extract low level features that can be used to drive the selection and combination of the best algorithm(s) for each image. The classification based color constancy was based on two algorithms i.e. class based algorithm and feature based algorithm. The former was used to assign each image to either indoor or to outdoor class whereas the latter select which automatic white balance (AWB) algorithm was used for each image. They had described how the problem of estimating illuminant and color

correction was deeply entwined with the one of color space transformation and also highlight research trends in these fields.

Li (2011) [2] demonstrated some dominant combinational strategies systematically, and divide them into three categories. These were individual color constancy, Data driven direct combination (DDDC) and Image Characteristics Guided Combination (ICGC). The former category finds the weight of each individual color constancy method through their estimations. While the latter category determine weights based on some kinds of image content features. The experiments were performed on three real-world image data sets in terms of the angular error and the perceptual Euclidean distance. It was found that combinational strategies with training procedure always generate better performance.

Brown et al. (2012) [7] presented the concept of color strength which was defines as combination of intensity and saturation information. It was used to describe when hue information in a scene was reliable. The advantage of using color strength model was that it can be used to estimate the reliability of the color information contained in a pixel. To perform the operation model was tested on two datasets with ground-truth color information and in both datasets the color strength model had strong analytical power for hue error. The author had demonstrated that pixels with the lowest color strength would provide the important information for color correction for four standard color constancy methods. It can be used to improve the performance of many other algorithms which rely on hue information such as image retrieval by color, object tracking, and person re-identification.

Corel et al. (2012) [3] presented the difficulty in computer vision where under changing illumination finding color representations were stable. The authors had proposed a method that had been based on physical constraints or statistical assumptions derived from the scene. They demonstrate the category hypothesis, where set of possible illuminates were weighted according to their capacity to map the corrected image onto specific colors.

Negrete et al. (2012) [4] had presented two recognized color constancy algorithms i.e. white patch Retinex (WPR) and Gray world algorithm in combination with gamma correction. They had studied their effect by applying these algorithms individually and in combination. The performance was evaluated by comparing the Average Power Spectrum Value of the test images and their following results. It was observed that the application of the gamma correction after a color constancy algorithm results in an improved image quality.

Khan et al. (2012) [11] presented that under illumination source the illumination correction was independent of ability of humans for solving the visible colors of objects in a given scene. The five CC approaches namely Gray-Edge CC, Gray-World CC, max-RGB CC, Shades-of- Gray CC and Bayesian CC was studied for the YCbCr skin filter. The effect of CC algorithms on skin segmentation algorithms was observed and it was found that CC algorithms before applying static skin classifiers and filters improves performance.

Bianco et al. (2008) [13] presented an improved illuminant

estimation accuracy by an image classifier which was trained to classify the images as indoor and outdoor. This was chosen as indoor and outdoor classification as the images of these classes present different content and was taken under different illumination conditions. Then the best algorithm was selected for each class by performing different experiments. The authors had investigated an indoor/outdoor parameterization strategy which represent a color constancy algorithm, whose parameters were set on the basis of the class predicted by the classifier whereas an indoor/outdoor algorithm selection strategy according to which the best algorithm are set on the basis of the class predicted by the classifier.

Weijer et al. (2007) [5] investigated a new approach known as edge-based color constancy. This technique was derived from grey edge hypothesis which states that the average reflectance of surfaces in the world is achromatic. It was based on derivative structure of images whereas existing color constancy algorithms were based on zero-order structure of images.

Agarwal et al. (2006) [15] demonstrated that color strength to illumination difference is important for video tracking algorithm. The authors had presented a review of well-known color constancy approaches. They examined whether these approaches can be applied to the video tracking problem. It was grouped into two categories first one is Pre-Calibrated and second one is Data-driven approaches. The color constancy problem, implementation assumption of color constancy approaches, and problem statement for tracking drawbacks were discussed.

Weijer (2005) [6] proposed a new approach for color constancy named as Grey- World assumption which states that the average reflectance of surfaces in the world is achromatic. Two well-known algorithms Grey-World hypothesis and the max-RGB method were shown to be two instantiations of a Minkowski norm based color constancy method. The Grey-Edge hypothesis assumed that the Minkowsky norm of derivatives of the reflectance of surfaces is achromatic. Then they test the algorithms on a large data set of images under different illuminates. The results showed that the new technique performs better than the Grey-World assumption and the max-RGB method.

Cohen (2011) [9] examined that human visual system was color constant to large amount whereas digital cameras had to depend upon fast color balancing algorithms, integrated into their image signal processing (ISP) pipeline so that it estimate the illumination in a scene and correct it digitally. The author had separated the correction stage into two parts one was diagonal correction before the demosaicing stage and a linear correction after the stage that could result in better image quality.

4. Need and significance of the research work

We provide a brief summary of literature search in previous section. The human visual system features color constancy [1] – [5], meaning that the apparent color of objects stay relatively constant under unreliable lighting circumstances. It enables the users to identify objects, as being a reliable color despite of lighting environments. For example, a blue shirt will look blue under direct sunlight and it will also look blue under fluorescent light.

However, if we had to determine the actual reflected light coming from the shirt under these two conditions, we would see that they fluctuate. This is where problems arise. When the picture is taken by digital camera, its colors just seemed incorrect. This is because the cameras do not have the ability of color constancy. Providentially, we can adjust this by using color constancy technique. Thus adjusting the color in more efficient way is the main motivation of this research work. Thus, the problem taken for this research work is divided into some objectives which are as follows.

5. Proposed algorithm

This section contains the various steps to achieve the objectives of this research work: Figure 5.1 has shown various steps required to get the final image using the proposed algorithm. Subsequent are the various steps with brief detail:-

Step 1: First of all given image will be acquire and converted into a digital image to apply vision processing operations.

Step 2: Now saturation color points will be removed i.e. the colors which are heavily affected by the light source.

Step 3: Now effect of the light will be removed using the edge based 2nd order derivation color constancy algorithm.

Step 4: After measuring the light source; color normalization will come in action to balance the effect of the poor light.

Step 5: Now bilateral filter will be applied on the output of edge based 2nd order derivation color constancy algorithm to reduce the effect of the noise.

Step 6: Now histogram stretching will be applied to get the final color constant image.

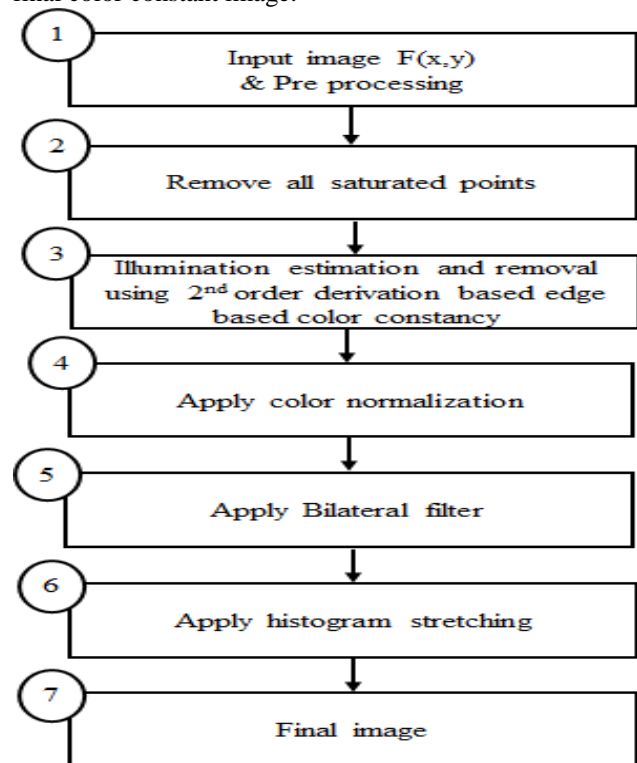


Figure 5.1 Flowchart of the proposed algorithm

6. Experimental set-up

In order to implement the proposed algorithm, design and implementation has been done in MATLAB using image processing toolbox. In order to do cross validation we have implemented the edge based color constancy with bilateral filter. Table 1 is showing the various images which are used in this research work. Images are given along with their formats. All the images are of different kind and each image has different kind of the light i.e. more or less in some images.

Table 1. Experimental images

S.No	NAME	FORMAT
1	image1	JPEG
2	image2	JPEG
3	image3	JPEG
4	image4	TIFF
5	image5	JPEG
6	image6	JPEG
7	image7	JPEG
8	image8	JPEG
9	image9	JPEG
10	image10	JPEG

7. Experimental results

For the purpose of cross validation we have taken 10 different images and passed to the edge based using first order, edge based using second order, and proposed algorithm. Subsequent section contains a result of one of the 10 selected images to show the improvisation of the proposed algorithm over the other techniques.

Figure 7.1 has shown the input image for experimental purpose. The image has low brightness and the impact of red color on the image is more. The overall objective is to improve the brightness of the image and to remove the effect of the color of the light source.



Figure 7.1: Input image



Figure 7.2: Edge based using first order

Figure 7.2 has shown the output image taken by the Edge based using first order. The image has contained more brightness and some more effect of the red color. However the problem of this technique is found to be some artifacts which have degrades the quality of the image.



Figure 7.3: Edge based using second order

Figure 7.3 has shown the output image taken by the Edge based using second order. The image has contained too much brightness and some more effect of the green color. However the problem of this technique is found to be is the effect of the green channel has not been minimized as expected.



Figure 7.4: Improved edge based using second order

Figure 7.4 has shown the output image taken by the integrated technique of the bilateral filter with edge based using second order. The image has contained too much brightness but still has more effect of the red color.



Figure 7.5:Final proposed image

Figure 7.5 has shown the output image taken by the integrated technique of the bilateral filter with edge based color constancy. The image has contained the balanced brightness and the impact of the red channel is also reduced. Comparing with other method the proposed has shown quite significant result with respect to all cases. The effect of the individual channel has also been normalized as well as the effect of the brightness is also normalized.

8. Performance analysis

This section contains the cross validation between existing and proposed techniques. Some well-known image performance parameters for digital images have been selected to prove that the performance of the proposed algorithm is quite better than the available methods.

Table 2 has shown the quantized analysis of the mean square error. As mean square error need to be reduced therefore the proposed algorithm is showing the better results than the available methods as mean square error is less in every case.

Table 3 is showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so the main goal is to increase the PSNR as much as possible. Table 3 has clearly shown that the PSNR is maximum in the case of the proposed algorithm therefore proposed algorithm is providing better results than the available methods.

Table 2. Mean Square Error

Image Name	Edge based- 1 st order	Edge based - 2 nd order	Proposed
1	0.0162	0.0133	0.0084
2	0.0064	0.0059	0.0049
3	0.0154	0.0144	0.0098
4	0.0395	0.0359	0.0338
5	0.0444	0.0418	0.0284
6	0.0253	0.0227	0.0115
7	0.0375	0.0351	0.0102
8	0.0311	0.0301	0.0193
9	0.0268	0.0228	0.0101
10	0.0172	0.0156	0.0104

Table 3. Peak Signal –to- Noise Ratio

Image Name	Edge based- 1 st order	Edge based - 2 nd order	Proposed
Img1	66.0482	66.8954	68.9092
Img2	70.0371	70.3957	71.2580
Img3	66.2616	66.5499	68.2200
Img4	62.1619	62.5826	62.8475
Img5	61.6559	61.9228	63.6032
Img6	64.1044	64.5666	67.5211
Img7	62.3854	62.6769	68.0528
Img8	63.2068	63.3470	65.2788
Img9	63.8515	64.5515	68.1005
Img10	65.7698	66.2062	67.9775

Table 4 is showing the comparative analysis of the Average Difference. As Average Difference needs to be minimized; so the main objective is to reduce them Average Difference as much as possible. Table 4 has clearly shown that Average Difference is less in our case therefore the proposed algorithm has shown significant results over the proposed algorithm.

Table 4. Average Difference

Image Name	Edge based- 1 st order	Edge based - 2 nd order	Proposed
Img1	0.0162	0.0133	0.0084
Img2	0.0064	0.0059	0.0049
Img3	0.0154	0.0144	0.0098
Img4	0.0395	0.0359	0.0338
Img5	0.0444	0.0418	0.0284
Img6	0.0253	0.0227	0.0115
Img7	0.0375	0.0351	0.0102
Img8	0.0311	0.0301	0.0193
Img9	0.0268	0.0228	0.0101
Img10	0.0172	0.0156	0.0104

Table 5 is showing the comparative analysis of the Mean Absolute Error. Mean Absolute Error contains the average difference between input and output image. Table 5 has clearly demonstrated that the Mean Absolute Error is quite less in the case of the proposed algorithm; therefore proposed algorithm is providing better results.

Table 5. Mean Absolute Error

Image Name	Edge based- 1 st order	Edge based - 2 nd order	Proposed
Img1	0.2033	0.1838	0.1300
Img2	0.0704	0.0677	0.0611
Img3	0.1730	0.1676	0.1152
Img4	0.3489	0.3319	0.2950
Img5	0.4782	0.4633	0.3214
Img6	0.3415	0.3232	0.1830
Img7	0.2858	0.2765	0.1221
Img8	0.3199	0.3145	0.2082
Img9	0.2223	0.2056	0.1159
Img10	0.2105	0.2002	0.1412

Table 6 shows the comparative analysis of the Normalized Cross-Correlation (NCC). As NCC needs to be close to 1, therefore proposed algorithm is showing better results than the available methods as NCC is close to 1 in every case.

Table 6. Normalized Cross-Correlation

Image Name	Edge based- 1 st order	Edge based - 2 nd order	Proposed
Img1	1.1832	1.1665	1.1159
Img2	1.0617	1.0596	1.0508
Img3	1.1603	1.1557	1.0973
Img4	1.3282	1.3143	1.2528
Img5	1.4737	1.4597	1.3489
Img6	1.3261	1.3101	1.1406
Img7	1.2723	1.2642	1.0662
Img8	1.3088	1.3042	1.2159
Img9	1.2042	1.1898	1.0855
Img10	1.1901	1.1815	0.9352

Table 7. Structural Co-relation

Image Name	Edge based- 1 st order	Edge based - 2 nd order	Proposed
Img1	0.7091	0.7303	0.7971
Img2	0.8836	0.8875	0.9026
Img3	0.7394	0.7455	0.8230
Img4	0.5637	0.5762	0.6226
Img5	0.4600	0.4690	0.5428
Img6	0.5666	0.5809	0.7505
Img7	0.6146	0.6228	0.8660
Img8	0.5822	0.5864	0.6695
Img9	0.6845	0.7021	0.8398
Img10	0.7006	0.7113	1.1126

Table 7 is showing the comparative analysis of the Structural Correlation. As SC needs to be close to 1, therefore proposed algorithm is showing better results than the available methods as SC is close to 1 in every case.

Figure 8.1 has shown the quantized analysis of the mean

square error. As mean square error need to be reduced therefore the proposed algorithm is showing the better results than the available methods as mean square error is less in every case.

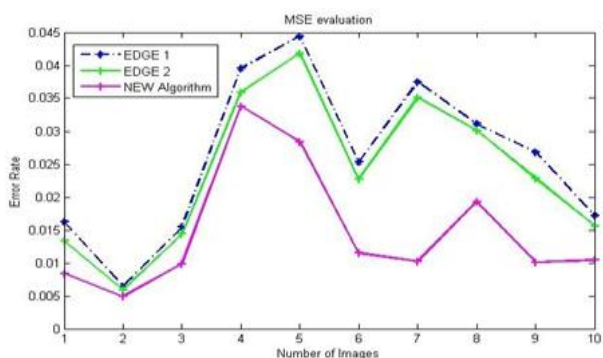


Figure 8.1: Mean Square Error

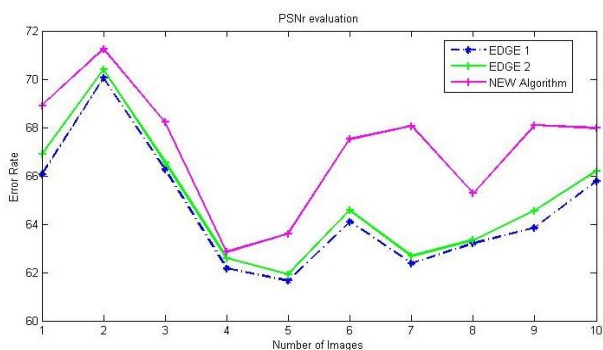


Figure 8.2: Peak Signal to Noise Ratio

Figure 8.2 is showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so the main goal is to increase the PSNR as much as possible. Table 3 has clearly shown that the PSNR is maximum in the case of the proposed algorithm therefore proposed algorithm is providing better results than the available methods.

Figure 8.3 is showing the comparative analysis of the Average Difference. As Average Difference needs to be minimized; so the main objective is to reduce them Average Difference as much as possible. Figure 8.3 has clearly shown that Average Difference is less in our case therefore the proposed algorithm has shown significant results over the proposed algorithm.

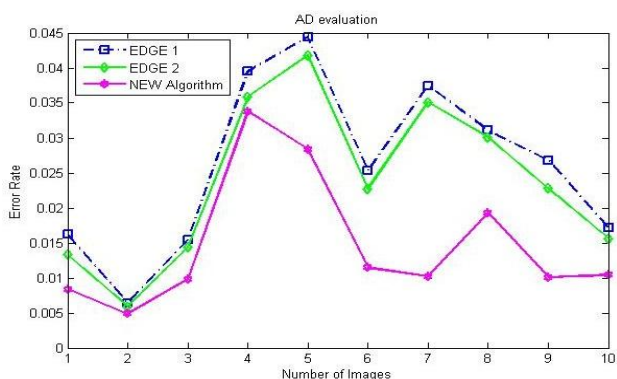


Figure 8.3: Average Difference

Figure 8.4 is showing the comparative analysis of the Mean Absolute Error. Mean Absolute Error contains the average difference between input and output image. Figure 8.4 has

clearly demonstrated that the Mean Difference is quite less in the case of the proposed algorithm; therefore proposed algorithm is providing better results.

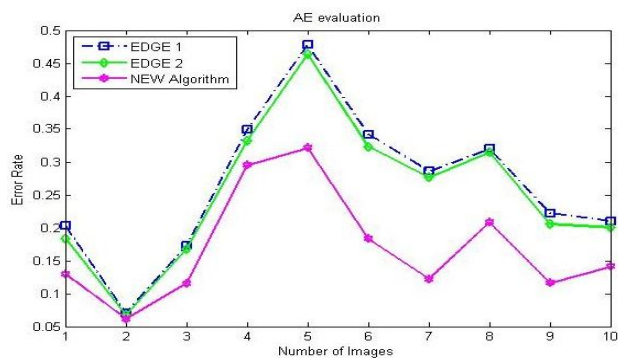


Figure 8.4: Mean Absolute Error

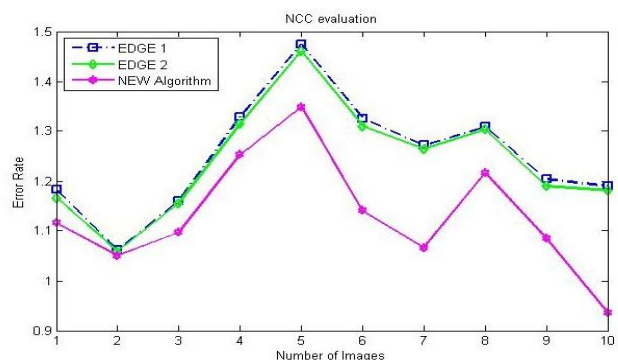


Figure 8.5: Normalized Cross-Correlation

Figure 8.5 is showing the comparative analysis of the Normalized Cross-Correlation (NCC). As NCC needs to be close to 1, therefore proposed algorithm is showing better results than the available methods as NCC is close to 1 in every case.

Figure 8.6 is showing the comparative analysis of the Structural Correlation. As SC needs to be close to 1, therefore proposed algorithm is showing better results than the available methods as SC is close to 1 in every case.

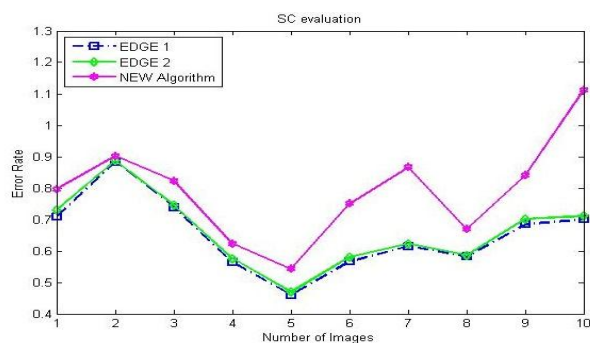


Figure 8.6: Structural Co-relation

5. Conclusion & Future work

This paper has proposed a new color constancy algorithm by integrating the 2nd order gray edge based color constancy algorithm with bilateral algorithm. The 2nd order derivative based edge based color constancy has ability to significantly improve the effect of the color light source. But it may introduce some Gaussian noise and also degrade the effect of the brightness in the image. So bilateral filter is used to remove the Gaussian noise and the histogram stretching is also used

improve the brightness of the image. The comparison of the proposed algorithm with other color constancy algorithms has shown the significant improvement over the available techniques.

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