Dermoscopy Image Enhancement Based on Color Constancy and Fuzzy Logic

[1]Sukhmeen Kaur, [2]Pawandeep Kaur
[1,2]Dept. of Electronics and Communication Tech., Guru Nanak Dev University, Amritsar, Punjab, India

Abstract
Dermoscopy images play a significant role in screening of skin related diseases. For proper melanoma diagnosis, gaining truthful color information in dermoscopy images is a very significant task. Images acquired under different dermoscopes having different illumination conditions suffer from problem of realistic color reproduction. This paper proposes a new color calibration channel which involves color correction and contrast enhancement of dermoscopy images. In the proposed method, edge based color constancy is integrated with membership function based fuzzy image enhancement which leads to removal of color artefacts turning the image to its originality and also enhances the contrast inside of lesion. The proposed approach is also compared with well known color constancy algorithms like grey world and shades of grey algorithm using statistical parameters showing supremacy over these algorithms.

Keywords
Color Constancy, Dermoscopy Images, Epilluminoscopy, Membership Function Based Fuzzy Image Enhancement, Image Color Normalization

I. Introduction

Over the past three decades, more people have had skin cancer than all other cancers combined [1]. The melanoma, a common form of skin cancer can also turn into life threatening disease if not diagnosed early. So, early detection is the promising strategy to cut the mortality rate of skin cancer [2] An estimated 76,380 new cases of invasive melanoma will be diagnosed in the U.S. in 2016 [3]. Nowadays dermatologists use dermoscopy, also known as 'eplluminoscopy'- for skin surface examinaton. As different hospitals use distinct dermoscopes having different illumination conditions that makes dealing with dermoscopy images a great challenging task. Thus, diagnosis of skin related diseases turns into tricky as well as complicated task. For these reasons, color calibration procedure is required to bring together the images before skin cancer diagnosis.

The color and contrast enhancement is not a new problem in dermoscopy images [4-9]. Haeghan et al [4] is first to propose color calibration approach in dermoscopy images In this paper, calibration is done by determining various camera parameters like camera offset, aperture and color gain . Grana et al [5] perform color normalization with the help of video microscope. As dermoscope illuminate central part of image therefore firstly, they corrected non-uniform illumination and after that relationship that is non-linear is computed between illumination and digital values obtained from camera. Wighton et al [6] proposed a method for calibration of inexpensive digital microscopes which leads to color correction and inconsistent lighting as well as radial distortion correction also known as chromatic aberration. Quintana et al [7] proposed new formulation in which dermoscopy lighting system spectral distribution is taken into account while computing transformation matrix for both RAW and JPEG images. Lyatomi et al [8] proposed software based calibration system in which information about camera parameters and transformation matrices is not needed. Barata et al [9] gives different direction to dermoscopy images color calibration. The author takes into account different color constancy algorithms as pre processing step which are well suited to color calibration of dermoscopy images.

One of the most amazing ability of Human Vision System, Color Constancy, which enables perceived color objects to be invariable with change in color of light source. But Machine Vision System is not able to adapt to these changing illumination conditions which is a great challenging task. A common solution to such challenging task is to first estimate the scene illuminant, which is then used to correct color biased images to get the so called canonical images under a white light source [10]. Based on these various color constancy algorithms has been introduced. In this paper, efficient method of color calibration of dermoscopy images is presented. Various well known algorithms for color constancy like Grey World [11], Shades of Grey[12] are implemented and are compared with proposed algorithm which is integration of Grey Edge based on Second Order derivative and membership function based fuzzy image enhancement. We achieve improvement in parameters like Peak Signal to Noise ratio, Mean Square Error, Bit Error rate etc. This method reduces the color artefacts and also preserves brightness and improves contrast inside of lesion.

II. Proposed Framework

In this section, the proposed framework for improving dermoscopy image quality is presented which is based on color constancy algorithm based on second order edge derivative. The proposed algorithm is designed by finding out gaps in algorithms that exist and is considered as new research work in improving dermoscopy image quality. The steps followed in proposed framework are as follows –

A. Image Acquisition

The image taken for processing is skin lesion or melanomas taken with dermoscope. Dermoscopes either have image capture system that is inbuilt or have attached camera for dermoscopy photography.

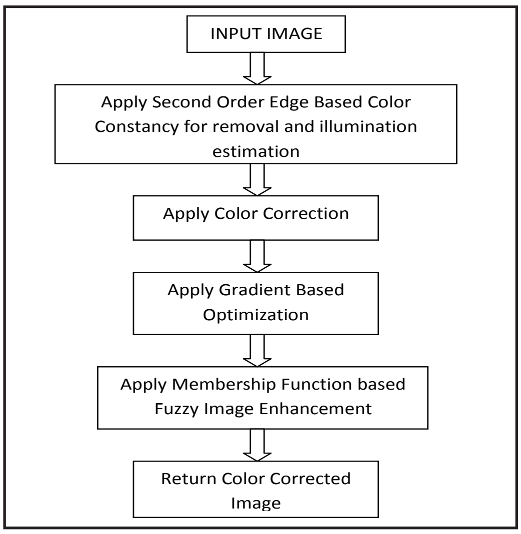

Fig. 1: Proposed Framework

B. Illumination Estimation on the basis of Second Order Edge Based Color Constancy

Color constancy transfers the color of an image acquired under unfamiliar light source, so that it appear indistinguishable to color under known light source. To achieve color constancy is difficult task, since image is product of scene illumination, surface reflectance properties and camera sensitivity function.

Illumination estimation based on second order grey edge is done in the second step as it is beneficial for improving edge details and also considers eight neighboring pixels. To incorporate derivative information (edges), pixel based methods are expanded which results in Grey Edge algorithm. In the Grey Edge Assumption, the image average color derivative can be evaluated from light source color given by [11]

$$\frac{\int g(x)dx}{\int dx} = ke \qquad (1)$$

Where,

$|g_X(x)| = (|R_X(x)|, |G_X(x)|, |B_x(x)|)^T$

The Grey Edge Algorithm originates from observation that image color derivative distribution forms a relatively regular, ellipsoid like shape of which long axis coincide with color of light source as given by [11]

$$\left[\int \left|\frac{\partial^n g^\sigma(x)}{\partial x^n}\right|^p dx\right]^{1/p} = ke^{n,p,\sigma} \qquad (2)$$

According to equation given above, color constancy assumes achromatic minkowski norm of reflectance derivative of scene. Different estimation for color based illumination on the basis of variables n,p,σ is noticed from this framework.

1. The image structure order n determines whether algorithm is Grey World or Grey Edge. RGB values form the basis of Grey World method where as Grey Edge method are dependent on spatial order n of derivatives .In this paper, order of edge based color constancy upto 2 is taken into consideration.
2. Minkowski norm p is considered for final illuminant color estimation from which multiple measurement weights which are relative are determined.
3. The local measurement scale σ is taken in combination with differentiation operator which is evaluated from Gaussian derivative.Gaussian smoothing operation impose local scale σ for Grey World Methods of Zero Order.

C. Image Correction Model

As illumination estimation and color correction is main aim of color constancy algorithm. After light estimation, to obtain standard output image correction, image correction mechanism comes into play. For input image color correction, source light chromaticity must be known. The conversion of image under unfamiliar source of light to image under canonical light source is known as adaptation. Von Kries model [13] is used for image correction. After light source color estimation, input image taken under unfamiliar source of light is transformed into image under known light source. The color correction diagonal model is given by

$$g_t = F_{u,t}\, g_u \qquad (3)$$

Where g_u represents unfamiliar light source image and g_t represents image under known light source and $F_{u,t}$ is diagonal matrix whose main purpose is color mapping.

$$\begin{bmatrix} R_c \\ G_c \\ B_c \end{bmatrix} = \begin{bmatrix} f_1 & 0 & 0 \\ 0 & f_2 & 0 \\ 0 & 0 & f_3 \end{bmatrix} \begin{bmatrix} R_u \\ G_u \\ B_u \end{bmatrix} \qquad (4)$$

Since this model is merely illumination light source estimation and does not accurately demonstrate photometric changes.

D. Gradient Based Optimization

Edge based color constancy uses image derivatives for illumination estimation. As different edge types exist. So to prevent the loss of these edge types, edge preservation is needed that is gradient based optimization [14]. Therefore gradient based optimization is used along with edge based color constancy for preserving the edge details.

E. Membership Function Based Fuzzy Image Enhancement

The use of membership function based fuzzy image enhancement [15] get widespread acceptance for enhancing low contrast images. Also when modification of image is done from its originality, image contrast gets affected. Therefore, membership function based fuzzy image enhancement along with color constancy and gradient based optimization provides much better results. Moreover, it is consistent to enhance contrast inside lesions and also in between lesion and surrounding skin in dermoscopy images.

The fuzzy enhancement method uses HSV color space obtained by converting RGB to HSV color space. Then enhancement of only V component is done by preserving chromatic information (hue and saturation). After that fuzzy based image enhancement is applied in which fuzzy histogram is computed. Fuzzy histogram mainly makes dark pixels darker and bright pixels brighter [15]. Then on the basis of local maxima, fuzzy histogram is divided into sub histograms. A local maximum is calculated on the basis of fuzzy histogram First and Second Order Derivative. Then sub histogram obtained on the basis of local maxima is equalized separately on the basis of DHE [16]. Dynamic histogram equalization uses spanning function based on total number of pixels. Then partitioned histogram is equalized and after that brightness is preserved. Then enhanced V component is combined with H and S component. Then image is again converted from enhanced HSV_e to RGB_e color space.

III. Results and Discussions

In this section, performance evaluation of Proposed algorithm is done by using dermoscopy images. To maintain originality of image, light source color that is inherent due to different dermoscopes used is removed and lesion boundary also become clearer. Fig. 2 to fig. 6 shows the resulting images obtained using different algorithms. Best visual representation is provided by the proposed algorithm.

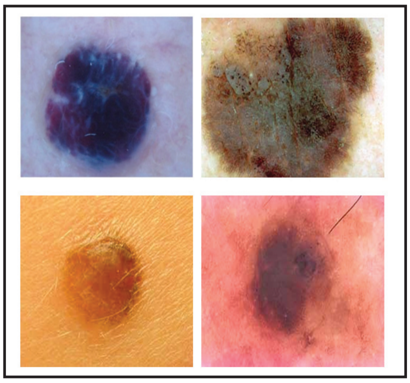

Fig. 2: Dermoscopy Images Taken Under Different Illuminations

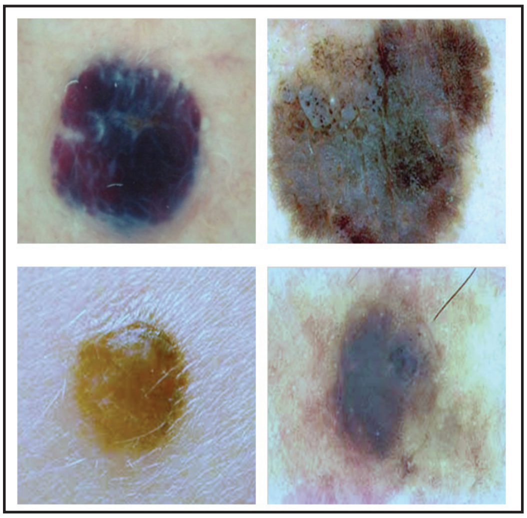

Fig. 3: Results of Grey World Algorithm

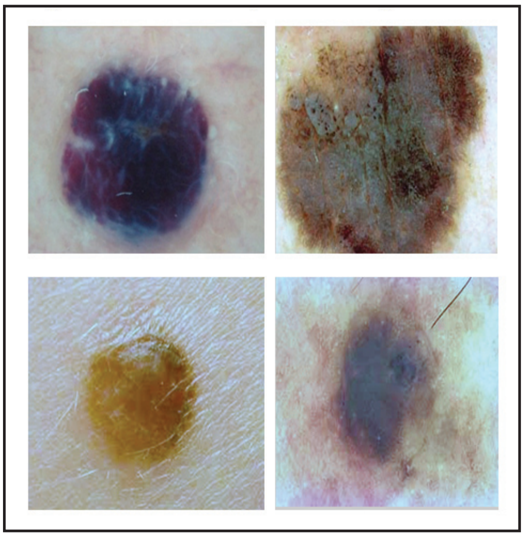

Fig. 4: Results of Shades of Grey Algorithm

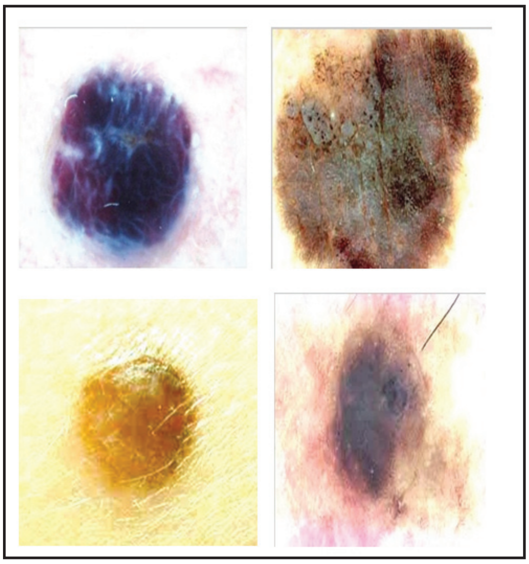

Fig. 5: Results of Proposed Algorithm

IV. Performance Evaluation

Mean Square Error, Peak Signal to Noise ratio and Normalized Cross Correlation are used to measure as well as compare the quality of Grey World algorithm, Shades of Grey algorithm and proposed algorithm.

A. Peak Signal to Noise Ratio

Peak signal to noise ratio is ratio between highest achievable signal value and corrupted noise power .Units used to measure this quantity is decibels. The higher value of PSNR corresponds to improved reconstructed image quality. PSNR is evaluated using equation [17]

$$PSNR = 10\ log_{10}\left(\frac{S^2}{MSE}\right) \qquad (5)$$

Where, s = 255

Table 1 shows proposed technique has highest PSNR as compared to other algorithms showing supremacy over them.

Table 1: PSNR Analysis

Images	Grey World	Shades of Grey	Proposed
1	58.3124	59.2836	70.5618
2	53.5346	56.2719	68.1550
3	54.6076	55.9674	72.7730
4	56.6742	58.1926	68.4835
5	55.6712	57.8281	77.1816
6	55.8236	57.4188	72.7730
7	56.3578	58.3308	70.3339
8	56.1425	58.4419	68.2361
9	56.6642	58.4416	72.5309
10	56.8584	62.1815	70.1010
11	55.9495	58.8380	76.8165
12	54.8737	57.0919	71.4642
13	56.0676	58.9304	71.4890
14	56.0312	60.4002	66.4245
15	57.2502	58.4496	72.4924

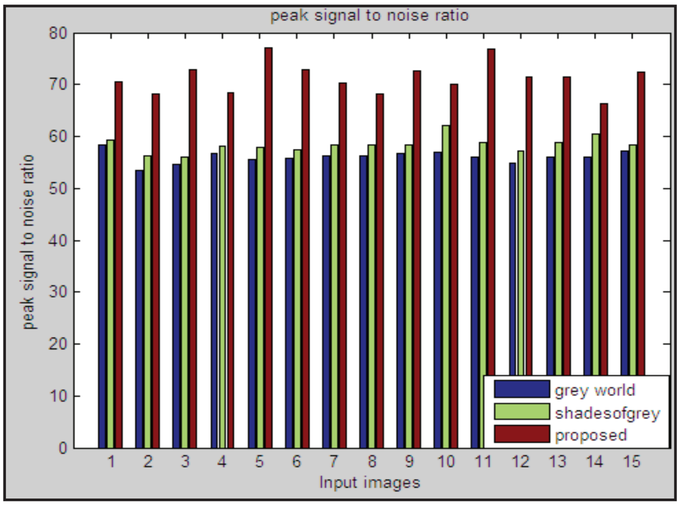

Fig. 6: PSNR Analysis

Fig. 6 shows Peak Signal to Noise ratio analysis from which it is clear that proposed algorithm provide better results than others.

B. Mean Square Error

Mean Square Error is representation of cumulative squared error between output and input image. It computes error between input and output images. It measures quality index of image. The lowest value of MSE corresponds to improved reconstructed image quality. MSE is evaluation using equation [17].

$$MSE = \frac{1}{mn}\sum_{k=1}^{m}\sum_{l=1}^{n}(J(k,l) - K(k,l))^2 \quad (6)$$

Table 2 shows that proposed algorithm has least mean square error showing better results than other algorithms.

Table 2: MSE Analysis

Images	Grey World	Shades of Grey	Proposed
1	0.1959	0.1215	0.0057
2	0.1881	0.1534	0.0099
3	0.1946	0.1646	0.0038
4	0.1399	0.0985	0.0092
5	0.1762	0.1072	0.0012
6	0.1340	0.0393	0.0064
7	0.1701	0.1178	0.0036
8	0.1504	0.0955	0.0060
9	0.1581	0.0931	0.0098
10	0.1765	0.1062	0.0036
11	0.2136	0.1652	0.0014
12	0.2117	0.1270	0.0041
13	0.1608	0.0832	0.0046
14	0.1622	0.0593	0.0148
15	0.0973	0.0929	0.0082

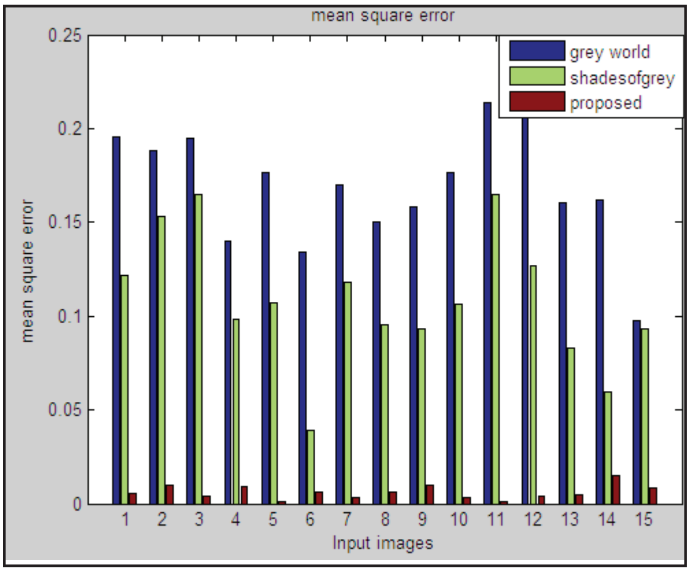

Fig. 7: MSE Analysis

Fig. 7 shows MSE analysis of different algorithms in which it is clear that proposed algorithm works better than others.

C. Root Mean Square Error

Root Mean Square Error measures difference between the values that model predicts and actual value observed.

$$RMSE = \sqrt{\frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(J(i,j) - K(i,j))^2} \quad (7)$$

Table 3 shows RMSE is lowest in case of proposed results showing improved and better results than other algorithms.

Table 3: RMSE Analysis

Images	Grey World	Shades of Grey	Proposed
1	0.4426	0.3570	0.0756
2	0.4337	0.3917	0.0997
3	0.4411	0.4310	0.0616
4	0.3740	0.3139	0.0960
5	0.4197	0.3274	0.0353
6	0.3361	0.1984	0.0797
7	0.4124	0.3432	0.0597
8	0.3878	0.3090	0.0776
9	0.3976	0.3051	0.0988
10	0.4201	0.3290	0.0603
11	0.4622	0.4065	0.0363
12	0.4601	0.3564	0.0643
13	0.4010	0.2884	0.0679
14	0.4027	0.2435	0.1217
15	0.3119	0.3048	0.0138

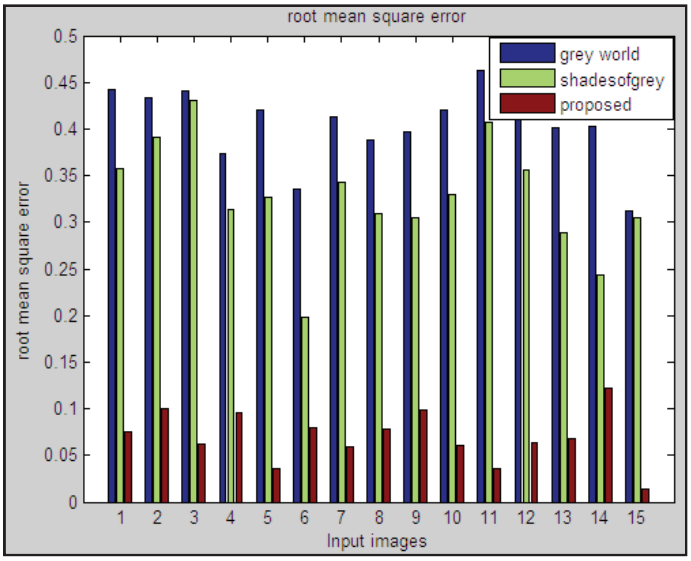

Fig. 8: RMSE Analysis

Fig. 8 shows RMSE value is minimum in case of proposed algorithm showing better results.

D. Normalized Cross Correlation

Normalized Cross Correlation is strength measure of linear relationship between two variables. It varies between -1 and +1 but it must be closer to 1 for better results. NCC is evaluated using equation [17]

$$NCC = \frac{\sum_{k=1}^{M}\sum_{l=1}^{N}(s(k,l)*t(k,l))}{\sum_{k=1}^{M}\sum_{l=1}^{N}(t((k,l))^2} \quad (8)$$

Table 4 shows that NCC is closest to 1 in case of proposed algorithm providing better results.

Table 4: NCC Analysis

Images	Grey World	Shades of Grey	Proposed
1	0.8194	0.8623	0.9272
2	0.6974	0.7776	0.9004
3	0.8379	0.8762	0.9508
4	0.8157	0.8630	0.8961
5	0.6430	0.7899	0.9741

6	0.8662	0.8801	0.9216
7	0.6169	0.6603	0.9417
8	0.8258	0.8910	0.9212
9	0.6817	0.7190	0.8926
10	0.8532	0.8475	0.9418
11	0.6984	0.7220	0.9752
12	0.8715	0.8905	0.9374
13	0.7833	0.8798	0.9135
14	0.6904	0.7226	0.8180
15	0.7439	0.8603	0.9307

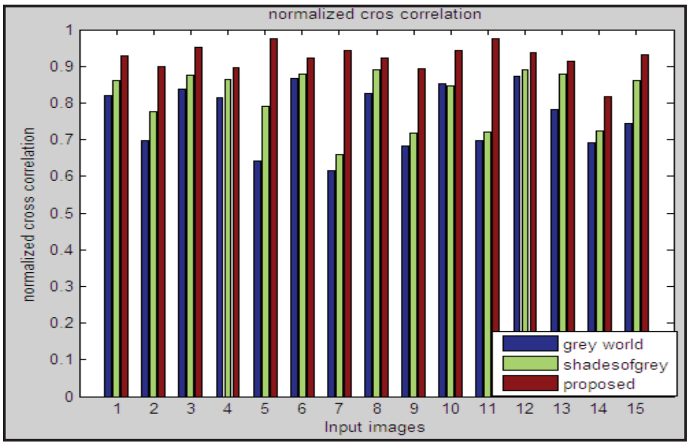

Fig. 9: NCC Analysis

Fig. 9 shows NCC analysis of proposed algorithm showing supremacy of proposed algorithm over other algorithms.

E. Bit Error Rate

Bit Error Rate is defined as error rate that occur in a transmission system that is number of bits in error per unit time. Bit error rate is ratio of number of bits in error and total number of bits that are transmitted. BER is evaluated using equation [17]

$$ber = \frac{number\ of\ erroreneous\ bits}{total\ number\ of\ transmitted\ bits} \quad (9)$$

Table 5 shows Bit Error Rate is lowest in case of proposed algorithm as compared to other algorithms. Therefore, it provides better results as compared to other algorithm.

Table 5: BER Analysis

Images	Grey World	Shades of Grey	Proposed
1	0.4426	0.3570	0.0756
2	0.4337	0.3917	0.0997
3	0.4411	0.4310	0.0616
4	0.3740	0.3139	0.0960
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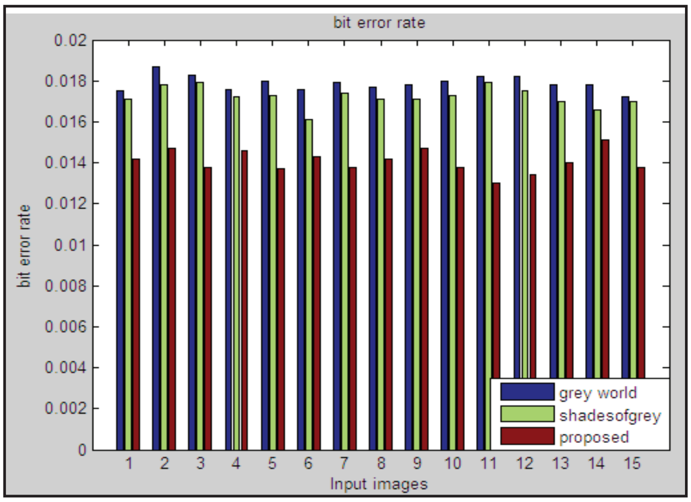

Fig. 10: BER Analysis

Fig. 10 clearly shows that BER is least in case of proposed algorithm showing better results than other algorithms.

V. Conclusion

This paper introduces new color constancy algorithm which is integration of second order Edge Based color constancy and Membership Function Based Fuzzy Image Enhancement. Existing algorithms like Grey World and Shades of Grey are compared with proposed algorithm. The proposed method provides more effective and efficient contrast enhancement. In dermoscopy images, the lesion feature has been further enhanced and all details are well preserved. Therefore, proposed algorithm can be effectively used for dermoscopy image analysis and CAD systems. The visual as well as statistical comparison of proposed algorithm with other color constancy algorithm shows significant improvement over available algorithms. In near future, neural network approaches can be used and image filters can also be used for denoising the images.

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