

Improved Dominant Brightness Level Based Color Image Enhancement Using Bilateral Filter

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Abstract: - Image enhancement plays a significant role in vision applications. It is used to improve the overall quality of the degraded images. Recently much work has been done in the field of remote sensing images enhancement. Many techniques were proposed so far for enhancing the remote sensing images. It has been found that the most of the existing techniques were based upon the transform domain methods; which may introduce the color artifacts and also may reduce the intensity of the input remote sensing image. To overcome this problem, a new integrated approach has been proposed which have the capability to enhance the contrast in remote sensing images in efficient manner by using the dominant brightness level analysis and gamma correction. The selection of the gamma correction seems to be justifiable as it has the ability to overcome the problem of reduction in illuminate of the existing methods. However to handle the short coming of transform domain method, bilateral filter has also been used to reduce the color artifacts. The algorithm has been designed and implanted in MATLAB using image processing toolbox. Comparative analysis has shown that proposed algorithm performs better as compared to existing techniques.

Keywords: - Image Enhancement, CLAHE, Bilateral Filter

1. Introduction

Image enhancement is usually simplest and appealing areas of digital image processing. Image enhancement is technique used to recover the overall quality of the corrupted images can be attained by using enhancement methods. It recovers the quality of poor images. Individual procedures have been estimated so far for receiving better the feature of the digital images. To recover picture superiority, image enhancement can clearly recover and bound some data available in the input image. The performance of dominant brightness level based image enhancement method has been evaluated. Dominant Brightness means that is efficient or impressible method for the images. Contrast enhanced images may include intensity distortion and lose image information in different regions. To overcoming the troubles of contrast enhanced images, decompose the input image into numerous layers of single dominant brightness levels. The image can be uniformly decomposed into unusual levels so that it can be easily handled.

1.1 Dominant Brightness Level Analysis

Contrast enhancement method is based on the dominant brightness level analysis and adaptive intensity transform for remote sensing images. This algorithm computes the

brightness- adaptive intensity transform function by means of the low frequency luminance element in discrete wavelet domain transform and transfer intensity values according to the transfer function. In this method discrete wavelet transform (DWT) decompose input image into set of band called HH, HL, LH and LL. LL sub band has explanation of low-,middle-,high-intensity layers by the log average luminance. Adaptive intensity transfer function estimation is done using the knee transfer function and gamma adjustment function is based on the dominant brightness level of each layer. After this process the enhanced image is obtained by using inverse DWT (IDWT).

1.2 CLAHE (Contrast Limited Adaptive Histogram Equalization)

Contrast Limited Adaptive Histogram Equalization (CLAHE) is a simplification of Adaptive Histogram Equalization (AHE). CLAHE was firstly developed for enhancement of low-contrast medical images. CLAHE vary from normal AHE in its contrast restrictive. CLAHE restricts the magnification by clipping the histogram at a user-defined value called clip limit. The clipping level conclude how much noise in the histogram should be smoothed and hence how much the contrast should be enhanced. A histogram clip (AHC) can also be applied. AHC automatically change clipping level and moderate over-enhancement of background regions of images.

1.2.1 CLAHE on HSV

HSV color space explains colors in terms of the Hue (H), Saturation (S), and Value (V). The model was formed by A.R. Smith in 1978. The dominant explanation for black and white is the term value. The hue and saturation level do not make a variation when value is at max or min intensity level. The HSV model acquire RGB components to be in the range [0; 1]. The value V is calculated by taking the maximum value of RGB or can be described formally by:

$$V = \max(R, G, B)$$

$$S = \frac{V - \min(R, G, B)}{V}$$

The saturation S is restricted by how usually separated the RGB values are. When the values are close together, the color will be close to gray. When they are far apart, the color will be stronger to pure.

Finally, Hue H , which concludes whether the color is red, blue, green, and yellow and so on, is the most difficult to calculate. Red is at 0° , green is at 120° , and blue is at 240° . The maximum RGB color controls the starting point, and the distinction of the colors decide how far we move from it, up to 60° away (halfway to the next primary color). To calculate the hue, we must calculate R' , G' , and B' :

$$R' = \frac{V - R}{V - \min(R, G, B)}$$

$$G' = \frac{V - G}{V - \min(R, G, B)}$$

$$B' = \frac{V - B}{V - \min(R, G, B)}$$

If $S=0$ then hue is undefined, otherwise

$$H = \begin{cases} 5 + B' & R = \max(R, G, B) \text{ and } G = \min(R, G, B) \\ 1 - G' & R = \max(R, G, B) \text{ and } G \neq \min(R, G, B) \\ R' + 1 & G = \max(R, G, B) \text{ and } B = \min(R, G, B) \\ 3 - B' & G = \max(R, G, B) \text{ and } B \neq \min(R, G, B) \\ 3 + G' & B = \max(R, G, B) \\ 5 - R' & \text{otherwise} \end{cases}$$

There is a hue discontinuity around 360° , arithmetic operations is hard to achieve in all components of HSV. Therefore, CLAHE can only be useful on V and S components. The enhanced image attained from CLAHE method that was applied on HSV color model is presented in Fig 1.2.1.



Fig1.2.1: The output of CLAHE applied on HSV color model

RGB color space explains colors in terms of the quantity of red (R), green (G) and blue (B) present. It uses additive color mixing, because it explains what kind of light wants to be emitted to generate a given color. Light is added to generate form from out of the darkness. The value of R , G , and B components is the total of the respective sensitivity functions and the incoming light:

$$R = \int_{300}^{830} S(\gamma)R(\gamma)d\gamma$$

$$G = \int_{300}^{830} S(\gamma)G(\gamma)d\gamma$$

$$B = \int_{300}^{830} S(\gamma)B(\gamma)d\gamma$$

where $S(\gamma)$ is the light spectrum, $R(\gamma)$, $G(\gamma)$, $B(\gamma)$ are the sensitivity functions for the R , G and B sensors respectively. In RGB color space, CLAHE can be applied on all the three components separately. The result of full-color RGB can be attained by joining the individual components. Fig. 1.2.2 shows output images before and after applying CLAHE.



Fig 1.2.2: The output of CLAHE applied on RGB color model.

2. Literature Survey

Nagi et al. (2014) [1] have proposed an approach that concurrently regulate contrast and enhances boundaries. Histogram has been designed to validate the results of different cases arising due to implementation of contrast stretching on image sharpening. The boundaries of the objects in the image are also enhanced by this method. Various other boundary enhancement techniques are also accessible like Contrast Stretching on Adaptive. This method shows much better result. **Bhattacharya et al. (2014) [2]** have proposed a fast algorithm to enlarge the contrast of an image nearby using singular value decomposition (SVD) approach and attempt to define some parameters which can give clues linked to the growth of the enhancement process. **Agarwal et al. (2014) [3]** have proposed a new technique named ‘‘Modified Histogram Based Contrast Enhancement using Homomorphic Filtering’’ (MH-FIL) for medical images. This technique uses two step processing, in first step global contrast of image is enhanced using histogram adjustment followed by histogram equalization and then in second step homomorphic filtering is used for image sharpening, this filtering if followed by image normalization. **Lee et al. (2013) [4]** have presented a novel contrast enhancement approach based on dominant brightness level analysis and adaptive intensity transformation for remote sensing images.

Firstly, they perform the discrete wavelet transform (DWT) on the input images and then decompose the LL sub-band into low, middle and high intensity layers using log-average luminance. Adaptive intensity transfer function is estimated using the knee transfer function and the gamma adjustment function. The resulting enhanced image is obtained by using the inverse DWT. This method can effectively enhance any low-contrast images acquired by a satellite camera and also suitable for other various imaging devices such as consumer digital cameras, photorealistic 3-D reconstruction systems and computational cameras. **Shamim et al. (2013) [5]** have presented a straightforward and efficient color image enhancement method for endoscopic images. The proposed image enhancement method works by two interconnected steps: image enhancement at gray level and color reproduction. At first, the captured RGB endoscopic image is converted into two-dimensional gray level spectral images using a well-known method called Fuji Intelligent Color Enhancement. In the next step the image with maximum entropy is chosen as the base image to be used for color reproduction. Maximum entropy value indicates the maximum enhanced image. The proposed method has been applied on any RGB images collected from any white light endoscopic devices. **Sun et al. (2013) [6]** have proposed a new optical transfer function-based micro image enhancement algorithm. In this algorithm, firstly, the point spread function has been acquired according the illogical clarification in the optical system. Secondly, the optical transfer function (OTF) was obtained and the high-pass filter based on optical property has been constructed through the microscopic OTF. Finally, micro image has processed by using the compensating filter. As a result, the clear and non-obvious Ringing effect micro image has gained. The optical transfer function-based micro image enhancement algorithm can generate a better micro image enhancement effects. **Teng et al. (2013) [7]** have discussed that the Laplacian pyramid of the image processing algorithm for image enhancement is an important field of image processing and critical technologies. The Laplacian pyramid is ever-present for decomposing images into several scales and is commonly used for image analysis. They have been described the necessary view of the Laplacian pyramid decomposition, and analysis using user-defined threshold values to differentiate between the image detail and edges of the disadvantages, and advise to use the global information directly to obtain the threshold value method. This method always produces high-quality results in the process of image detail enhancement. **Archana et al. (2013) [8]** have proposed a method that enhances an image with natural contrast. The aim of contrast enhancement is achieved using parameters 'a', 'b', 'c' and 'k', where 'a', 'b', 'c' and 'k' are constants with the new extension in their range. Local contrast enhancement increases the gray level of original image on the basis of light and dark edges. This method has applied on $m \times n$ size of an original gray scale image. The local mean and local

standard deviation of entire image, minimum value and maximum value of the image are used to statistically describe digital image. **Tianhe et al. (2012) [9]** have proposed multifractal theory analysis of infrared image and the multifractal uniqueness of edges in the infrared images has been extracted. The characteristics of each pixel in the image and its multifractal spectrum have been calculated. Then pixels are classified by Human visual system, which is more susceptible to the edge structure of image. From softness area to edge area, the pixels are weighted and enhanced. The edge pixels has been classified and enhanced in accordance with the susceptibility of human visual system to the edge shape of an infrared image. The image enhancement method is more accessible and highlights the human eyes susceptible image area. The difficulty of low visibility and blurry edge has been resolved well and the enhancement image is more appropriate to human's observing. **Chaofu et al. (2012) [10]** have proposed the homomorphic enhancement that can remove the control of irregular explanation in frequency domain algorithm. They have been offered a hybrid algorithm to enhance the image. They utilize the Gauss filter processing to enhance image details in the frequency domain and smooth the curve of the image by the top-hat and bottom-hat transforms in spatial domain. Through the hybrid algorithm to enhance the infrared image, not only enhanced the infrared image of the details, but the outline of the image has also been smooth. Finally, the enhanced image is better than other algorithm of results. **Weizhen et al. (2012) [11]** have proposed the theory of retinex and method of image enhancement that is based on experiments and study of vision. Retinex enhances the image by processing reflection R and incident light L from the image S to gain enhanced vision quality. They have been described that the image appears to reflect or transmit more or less of the light, varying from black to white for image and from black to colorless for transparent volume. For X-Ray medical images, they have been improved the global and local image enhancement by Retinex algorithm. **Yaping et al. (2012) [12]** have proposed a method including three steps: image preprocessing, image recognition and enhancement. The study of recognition and enhancement of the traffic sign for the computer generated image is very less. For recognition and enhancement of the traffic sign in the Computer generated image, the complexity is how to correctly identify and enhance the traffic sign, and maintaining other information of object do not been altered. The adopting stepwise refinement method attempts to solve the problem. The proposed idea of stepwise refinement provides a procedural reference for complex image recognition. **Suprijanto et al. (2012) [13]** have discussed the dental panoramic radiography is one of dental imaging. The digitized film-based image to digital image has been essential to let image enhancements in order to improve the interpretability quality of information in the image. Digitized film-based image has performed using a flatbed

scanner on transmission and reflection mode. The contrast quality of digital image that scanned using both modes has been estimated based on statistic image characteristic. Estimation of the preference image quality is performed based on objective principle. **Fang et al. (2011) [14]** have discussed that image enhancement can improve the view of information. An image taken from an actual scene can be separated into many regions according to the need for enhancement. One particular enhancement method improves various regions and really deteriorates the other regions which have no need for such enhancement or any enhancement at all. They have proposed a method to improve the enhancement outcome with image fusion method. Some unusual evaluation methods and fusion policies are discussed and compared. They have shown that the fusion improves the enhancement results. **Jin et al. (2011) [15]** have proposed an industrial X-ray image enhance algorithm based on histogram and wavelet. The proposed technique is capable to deal with low contrast and poor quality details. Firstly, the original image is separated by the contrast partial adaptive histogram equalization algorithm in order to alter entire contrast. Then a plan is build between the image and the detail scales by the wavelet fraction in order to altering the local contrast. Compared with other image enhancement algorithms, this algorithm can recover the global image contrast successfully as well as defeat the observable artifacts of X-ray image, the x-ray image turn into more clear, and an enhanced perceptual image is acquired for the image quality identify and identical. **Henan et al. (2011) [16]** have proposed an enhancement algorithm based on multi-scale Retinex which can make up the lack of conventional wavelet algorithm. The standard and recognition methods of multi-scale Retinex and wavelet has been calculated. The panchromatic and multicolor remote sensing image enhancement has been passed out based on the two methods and remote sensing images could get superior enhancement quality, so multi-scale Retinex is a better method for sensing image enhancement. **Hong et al. (2011) [17]** have proposed the logarithmic image processing (LIP) model which has been proved to be consistent with several laws and fit characteristics of the human visual system. They have utilized both the LIP model and consider characteristics of the human visual system (HVS) to propose a new multi-scale enhancement algorithm. Then a new measure of enhancement based on JND model (Just Noticeable Difference, JND) of human visual system has been proposed and used as a tool for evaluating the performance of the enhancement technique. This method can adjust the image dynamic range, enhance the image details and achieve a more pleasing and comfortable image.

3. Proposed Algorithm

The proposed contrast enhancement performs the DWT to decompose the input image into a set of four sub-bands

called HH, HL, LH, and LL sub-bands. The log-average luminance is computed in the LL sub-band because it has the illumination information for computing the dominant brightness level of the input image. The LL sub-band is decomposed into low, middle, and high intensity layers according to the dominant brightness level. The adaptive transfer function is computed in three decomposed layers using the dominant brightness level. Then the adaptive transfer function is applied for color-preserving high-quality contrast enhancement. All the contrast-enhanced layers are fused with the suitable smoothing and both the processed LL band and unprocessed LH, HL, HH sub-bands undergoes the IDWT. The final image is obtained by the bilateral filter.

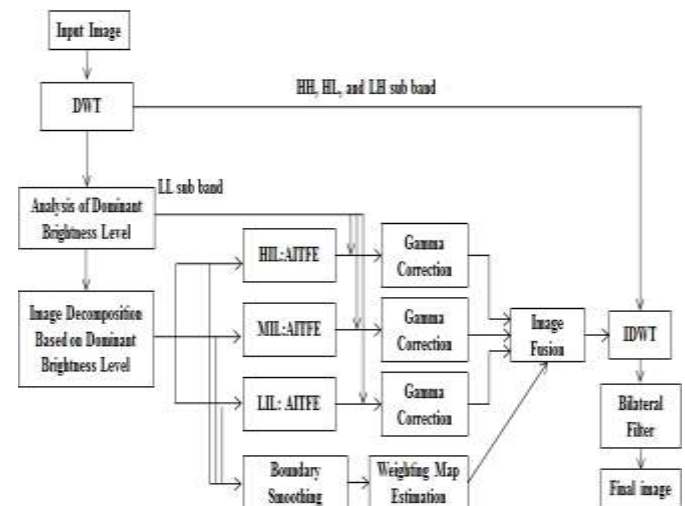


Figure 3.1 Flowchart of proposed algorithm

4. Experimental Results

In order to implement the proposed algorithm; design and implementation is done in MATLAB by using Image Processing Toolbox. For the purpose of cross validation we have taken 15 different images and passed to the different techniques and proposed algorithm. Subsequent section contains a result of one of the 15 selected images to show the improvisation of the proposed algorithm over the other techniques. We have shown the results on image 11. Fig 4.1 is showing the input image for experimental analysis.



Fig 4.1: Input Image

Fig 4.2 has shown the output taken by dominant brightness level analysis, CLAHE on HSV, CLAHE on RGB, and the proposed method. The proposed method enhances the contrast of an image in an efficient manner and also reduces the noise and color artifacts.



Fig 4.2: (a) Dominant Brightness Level Analysis (b) Proposed Algorithm © CLAHE on HSV (d) CLAHE on RGB

5. 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.

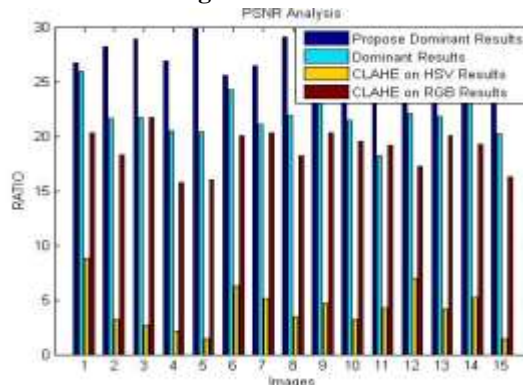
5.1 Peak Signal to Noise Ratio Evaluation

Table 5.1 is showing the relative 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 5.1 has clearly shown that the PSNR is maximum in the case of the proposed method therefore proposed method is providing better results than the available methods.

Test Images	Proposed Dominant Results	Dominant Results	CLAHE on HSV Results	CLAHE on RGB Results
1	26.6695	25.9560	8.8535	20.3132
2	28.2185	21.5794	3.2151	18.2765
3	28.8880	21.7359	2.6372	21.7161
4	26.9251	20.5115	2.1888	15.7278
5	29.9354	20.3711	1.4297	15.9983
6	25.5781	24.2747	6.2348	20.0487
7	26.4873	21.1238	5.1486	20.3421
8	29.0460	21.8571	3.4605	18.1876
9	29.7423	23.1339	4.7331.	20.3348

10	28.0448	21.4191	3.2089	19.5334
11	24.3468	18.2097	4.2193	19.1932
12	26.8275	22.0242	6.9697	17.2601
13	28.2631	21.7659	4.2049	20.0218
14	27.6386	23.5068	5.2494	19.2603
15	27.0249	20.2139	1.4474	16.2584

Table 5.1: Peak Signal to Noise Ratio Evaluation



Graph 5.1: PSNR of Proposed Dominant Brightness, Dominant Brightness, CLAHE on HSV, CLAHE on RGB for different images

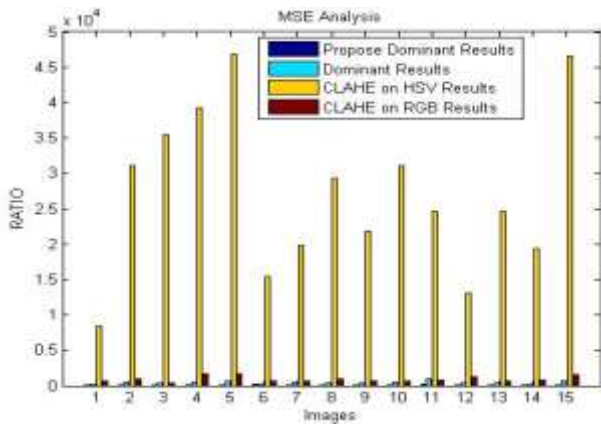
It is very clear from the plot that there is increase in PSNR value of images with the use of proposed method over other methods. This increase represents improvement in the objective quality of the image.

5.2 Mean Square Error Evaluation

Table 8.2 is showing the quantized analysis of the mean square error. As mean square error need to be reduced therefore the proposed method is showing the better results than the available methods as mean square error is less in every case.

Test Images	Proposed Dominant Results	Dominant Results	CLAHE on HSV Results	CLAHE on RGB Results
1	140	165	8467	605
2	98	452	31015	967
3	84	436	35429	438
4	132	578	39283	1739
5	66	597	46785	1634
6	180	243	15474	643
7	146	502	19871	601
8	81	424	29311	987
9	69	316	21866	602
10	102	469	31059	724
11	239	982	24612	783
12	135	408	13065	1222
13	97	433	24694	647
14	112	290	19415	771
15	129	619	46595	1539

Table 5.2: Mean Square Error Evaluation



Graph 5.2: MSE of Proposed Dominant Brightness, Dominant Brightness, CLAHE on HSV, CLAHE on RGB for different images

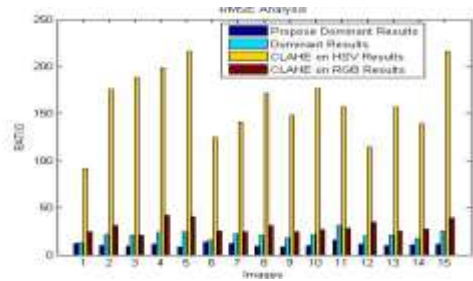
It is very clear from the plot that there is decrease in MSE value of images with the use of proposed method over other methods. This decrease represents improvement in the objective quality of the image.

5.3 Root Mean Square Error Evaluation

Table 8.3 is showing the quantized analysis of root mean square error. As root mean square error needs to be reduced therefore the proposed method is showing the better results than the available methods as root mean square error is less in every case.

Test Images	Proposed Dominant Results	Dominant Results	CLAHE on HSV Results	CLAHE on RGB Results
1	11.8322	12.845	92.0163	24.5967
2	9.8995	21.2603	176.1108	31.0966
3	9.1652	20.8806	188.2259	20.9284
4	11.4891	24.0416	198.1994	41.7013
5	8.1240	24.4336	216.2984	40.4228
6	13.4164	15.5885	124.3945	25.3574
7	12.0830	22.4054	140.9645	24.5153
8	9	20.5913	171.2046	31.4166
9	8.3066	17.7764	147.8716	24.5357
10	10.0995	21.6564	176.2356	26.9072
11	15.4596	31.3369	156.8821	27.9821
12	11.6190	20.1990	114.3022	34.9571
13	9.8489	20.8087	157.1432	25.4362
14	10.5830	17.0294	139.3377	27.7669
15	11.3578	24.8797	215.8588	39.2301

Table 5.3: Root Mean Square Error Evaluation



Graph 5.3: RMSE of Proposed Dominant Brightness, Dominant Brightness, CLAHE on HSV, CLAHE on RGB for different images

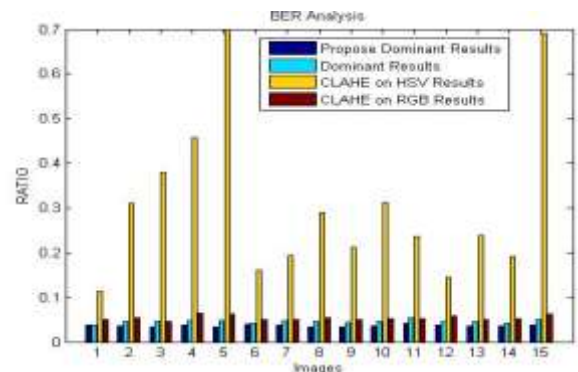
It is very clear from the plot that there is decrease in RMSE value of images with the use of proposed method over other methods. This decrease represents improvement in the objective quality of the image.

5.4 Bit Error Rate (BER)

Table 8.4 is showing the quantized analysis of bit error rate. As bit error rate needs to be reduced therefore the base paper method is showing the better results than the available methods as bit error rate is less in every case.

Test Images	Proposed Dominant Results	Dominant Results	CLAHE on HSV Results	CLAHE on RGB Results
1	0.0375	0.0385	0.1129	0.0492
2	0.0354	0.0463	0.3110	0.0547
3	0.0346	0.0460	0.3792	0.0460
4	0.0371	0.0488	0.4569	0.0636
5	0.0334	0.0491	0.6994	0.0625
6	0.0391	0.0412	0.1604	0.0499
7	0.0378	0.0473	0.1942	0.0492
8	0.0344	0.0458	0.2890	0.0550
9	0.0336	0.0432	0.2113	0.0492
10	0.0357	0.0467	0.3116	0.0512
11	0.0411	0.0549	0.2370	0.0521
12	0.0373	0.0454	0.1435	0.0579
13	0.0354	0.0459	0.2378	0.0499
14	0.0362	0.0425	0.1905	0.0519
15	0.0370	0.0495	0.6909	0.0615

Table 5.4: Bit Error Rate Evaluation



Graph 5.4: BER of Proposed Dominant Brightness, Dominant Brightness, CLAHE on HSV, CLAHE on RGB for different images

It is very clear from the plot that there is decrease in BER value of images with the use of proposed method over other methods. This decrease represents improvement in the objective quality of the image.

6. Conclusion and Future Scope

In this paper, a new integrated approach has been proposed which has the capability to enhance the contrast in remote sensing images in efficient manner with the usage of the dominant brightness level analysis and gamma correction. To handle the short coming of transform domain method, bilateral filter has also been used to reduce the color artifacts. The proposed algorithm has been designed and implemented in MATLAB. Experimental results has shown that the proposed algorithm performs better as compared to existing algorithms when compared on the basis of various performance metrics.

This paper has not considered foggy or disturbed images, so in near future, further enhancement will be made by modifying the proposed algorithm to enhance foggy as well as hazy disturbed images.

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