A Comparative Study on Image Contrast Enhancement Techniques

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Abstract - *In the process of enhancement of image quality of different types of images which have huge applications in the number of areas of real world the contrast and brightness are two main concerns. For the sake of human interpretation not only the objective as well as subjective quality also matters. For subjective quality evaluation main parameter is the contrast present in every part of the image. Contrast rises if there is a contrast variation in the amount of luminance reflected from the two adjacent surfaces. Researchers have proposed various techniques for contrast enhancement in image processing while ignoring the illumination parameter present in the digital images. Main aim for the contrast enhancement of the images is for enhancing the details present of the objects present in the image. Image contrast enhancement is possible if stretching of pixel values is performed of a particular range where contrast improvement is needed. In tonal enhancement, there are many regions present in the digital image where darkness and brightened regions are more prone to variations and this scenario accurate and smooth contrast enhancement is required. In this present research work, there is a comparative analysis of various contrast enhancement of different color images is performed. Various techniques like Histogram equalization, brightness preserving technique and other techniques outcomes are discussed in detail with the help of various objective parameters.*

Key Words: Image contrast enhancement, image processing, color images, histogram equalization, entropy

1. INTRODUCTION

There are various color spaces in the real world and out of these two prime color spaces are RGB and CMYK and which are intended for various engineering and science communications.

1.1 RGB

This RGB color model is associated with the red, green and blue receptor is the retina of the eye of living beings. This color model is based on the additive color process where mixing of these colors produces other complimentary colors of the real world. It is the fundamental color model and which is the integral part of the color projected with the sun light. In the world of digital electronics, this model is used for graphics and also in printing applications. The secondary color like cyan, magenta and yellow are created by mixing two colors at a time from the red, green and blue colors. Cyan is produced by mixing green and blue, magenta is produced by mixing blue and red, yellow is produced by mixing red and green. If red, green and blue are mixed in full proportions then white color is produced and if there is no value of these colors then black color is produced.

There are various techniques which are utilized to improve the contrast of the digital image. Some of the techniques that are utilized for implementation of present research work have been discussed below.

1.2 HE (Histogram Equalization)

Histogram equalization is one of the contrast adjustment techniques that is utilized in digital image processing. In this process pixel values are adjusted so that histogram of original image is uniformed and normalized. This technique is used to improve the overall contrast of the internal parts of the image where either the pixels have low or high values regions. Since this method normalized the pixel values with the help of histogram way so this method is known as histogram equalization. This method is generally used to improve the overall contrast of the digital image in comparison to other region-based contrast improvement methods.

1.3 Gamma Correction

Gamma correction is a methodology that is helpful in obtaining enhanced brightness and luminance of the pixel by using some mathematical functions. This mathematical function is nonlinear in nature and monotonic that is used to affect the white and grey values as well as dark shadows pixel values in the digital image. Gamma correction is one of the tested techniques for particular applications.

1.4 Brightness Preserving Bi-Histogram Equalization (BBHE)

This technique was proposed by Y. T. Kim. In this method, author used the concept of dividing the histogram of the input digital image into two different parts. This process is based on the average of the image. So, this technique tries to equalize the two parts based on their respective histograms independently. This method is used to increase the contrast of the image where output image has brightness near to average and mean grey level. This technique has numerous applications in various areas of image processing. This technique is primarily used to enhancing the contrast of the image in addition to preserving the mean brightness of the input digital image.

1.5 Brightness Preserving Dynamic Histogram Equalization

This technique is implemented to solve the limitations of the histogram equalization method. Histogram equalization shows saturation effect in electronics devices so this can be solved by preserving the brightness of the input image in the output image also. BPDHE tries to preserve the brightness of input image into the output image also. Method uses gaussian filter and then uses partition method based on local maxima. Here each partition of the image will have new dynamic range. In the final stage, output image is normalized based on the input image mean brightness value.

1.6 Region Based Adaptive Contrast Enhancement (RACE)

This whole algorithm is split into following steps

1) A central point is considered based on threshold of each region that will act as a seed point for that region

2) Now this central point is used to split image into foreground and background regions.

3) Foreground region is then enhanced by equalizing histogram adaptively and then background region is added to the enhanced foreground.

4) In the last step, gradient of the original image is calculated and added to the step 3 output so that enhanced image is obtained.

2. LITERATURE SURVEY

A. M et al. [2] proposed an automatic transformation technique that improved the brightness of dimmed images via the gamma correction and probability distribution of luminance pixels which used an efficient method for contrast and color enhancement of digital images as contrast of image is very important characteristic by which the quality of image can be judged as good or poor quality. It was composed of three major steps. In the first primary step, histogram analysis process was applied on the original image such that it was used to present the pixel data of the original image which was relied on probability as well as statistical transformation. In the subsequent second step, the process of distribution of weights was followed which is helpful in smoothing the fluctuation of intensities and computing the threshold of histogram so that stretching of pixels was achieved. In the third and final step, Adaptive gamma correction and Adaptive Histogram Stretching with respect to color constraint can automatically enhance the image contrast and color through use of a smoothing curve. The technique proposed here performed efficiently in different dark and bright images by adjusting their contrast very frequently and produced enhanced images of comparable or higher quality than conventional method.

A. Aggarwal et al. [3] proposed an algorithm which achieves contrast enhancement, also preserves the brightness level of the images. It included the discussion regarding the development of the image enhancement techniques and their application in the field of image processing. To process an input image so that the resultant image was more suitable than the original image for specific application is a principal objective of image enhancement techniques. This new algorithm was developed to overcome the problems of excessive contrast enhancement caused by Traditional global histogram equalization and block effect caused by local histogram equalization. In this, the weighted average of the histogram equalized, gamma corrected and the original image were combined to obtained the enhanced processed image. It had been shown by experimental results that proposed algorithm had good performance on enhancing contrast and visibility for a majority of images.

S. C. Huang et al. [5] proposed an efficient method to modify histograms and enhance contrast in digital images. Since enhancement plays a significant role in digital image processing, computer vision, and pattern recognition they presented an automatic transformation technique that improves the brightness of dimmed images with the help of methods like gamma correction as well as the probability distribution of luminant image pixels. For improving the quality of the input video, perform temporal information so that computational complexity could be lowered. From the outcome of the experiments, it was showed the worthiness of the proposed method. They had presented a novel enhancement method for both images and video sequences.

T. Celik et al. [6] suggested an algorithm which improves the contrast of the digital image by performing adaptive equalization process on histogram of the original image. This method utilized the Gaussian mixture model on the image grey level pixels. These Gaussian components were utilized to sectioned the dynamic range of input original image into grey level intervals of the pixels. From the outcome of the suggested algorithms, it was shown that the algorithm performed better in comparison to other algorithms. The one of the most significant methods was not setting any parameter manually for setting a particular dynamic range as well as its applicability on various types of digital images.

3. PARAMETERS USED FOR EVALUATION OF IMAGE ENHANCEMENT TECHNIQUES

For the objective measurement of any algorithm for image enhancement, there are various parameters on the basis of which performance of the algorithms is evaluated. The various parameters that are used to evaluate the performance of techniques are as follows.

(i) Entropy

$$-\sum_{s=1}^{256} h(s) \times \log_2 h(s)$$

where, h(s) is the normalized histogram of the output digital image. This parameter is utilized to measure the content of the image, with having higher range values showing digital images are richer in information.

(ii) Absolute Contrast Error or Color Error

Absolute Contrast Error is the difference between the deviations of the original image and the enhanced image. ACE should be as less as possible; it means the deviation of the output image should be more means the contrast enhancement is more.

(iii) Peak Signal to Noise Ratio (PSNR)

$$10\log_{10}\frac{255^2}{MSE}$$

Peak Signal to Noise Ratio parameter value should be high. It means that the content of image in the output is high with less noise.

4. RESULTS AND CONCLUSIONS

This chapter aims at providing the results of the algorithms of image enhancement techniques like Histogram Equalization (HE), Gamma Correction (GC), BBHE, BPDHE, Region based Adaptive Contrast Enhancement (RACE Approach), which have been described in previously and determine the best one for image enhancement.

All the enhancement techniques are implemented using MATLAB-2009a and its image processing toolbox. Enhancement techniques are applied on x ray bone images of different size like 512×512, 256×256, etc.

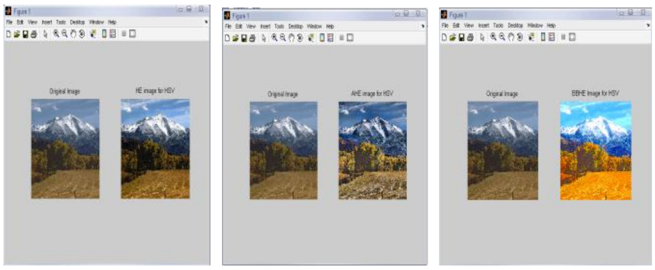
4.1 Results for HSV Color Model for 'Landscape' Image

Table -1: Results of Various Parameters for "LANDSCAPE" Image using HSV Color Model

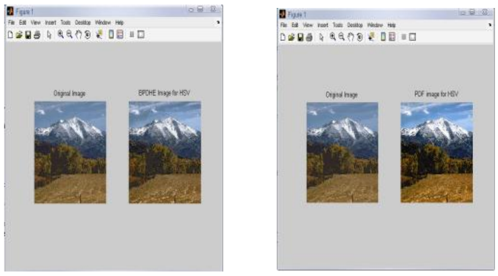
Parameter Vs Techniques	Error Color	CPSNR (dB)	Out Entropy		
			R	G	B
HE	0.0035	20.3588	7.6067	7.8049	7.2463
GC	0.0092	16.8459	7.8348	7.7362	7.8154
BBHE	0.2143	8.4782	6.3576	6.6669	4.1230
BPDHE	0.0029	26.5237	7.3836	7.5731	7.4151
RACE	0.0031	20.1979	7.6252	7.8005	7.2431

Input entropy of Landscape Image: R=7.2382, G=7.3182, B=7.4802

In the Table 1, different techniques are compared on the basis of various parameters for HSV color model. From this table, it is clear that value of error color for BPDHE is less as compared to the other techniques. It means that there is very little difference in the colors of the output image as compared to the input image even after enhancement. The value of CPSNR is more for BPDHE which is also desirable for any technique to work efficiently. More CPSNR means less noise entered during enhancement. In terms of entropy, the output entropy of R and G components are more as compared to input entropy in case of all the techniques except BBHE in which all component output entropy is less than input entropy.



(a) HE Image (b) GC Image (c) BBHE Image



(d) BPDHE Image (e) RACE Approach

Fig. -1: Images of "LANDSCAPE" after Equalization Using HSV Color Model

From the Fig. 1, it is clear that the visual quality of HE, BPDHE and RACE approach is good as compared to the others. But, only BPDHE is showing the best quality image in terms of color as the colors of the input and output image are almost same, while in others there is lot of variation in the color of the output image.

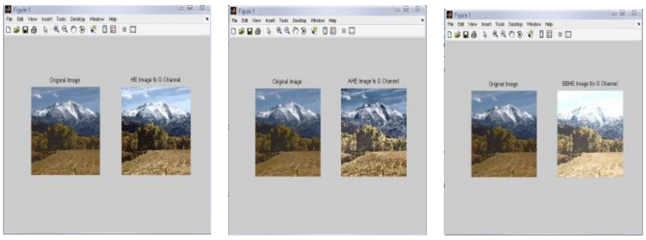
4.2 Results for G-channel of RGB Color Model for 'Landscape' Image

Table - 2: Results of Various Parameters for "LANDSCAPE" Image using G-Channel of RGB Color Model

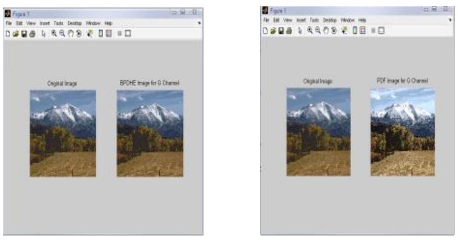
Parameter Vs Techniques	Error Color	CPSNR (dB)	Out Entropy		
			R	G	B
HE	0.1021	15.813	7.846	7.121	7.376
GC	0.0853	15.198	7.825	7.816	7.763
BBHE	0.3986	7.193	6.532	5.424	6.112
BPDHE	0.0001	35.024	7.328	7.052	7.507
RACE	0.1124	15.373	7.835	7.096	7.302

Input entropy of Landscape Image: R=7.2382, G=7.3182, B=7.4802

In the Table 2, different techniques are compared on the basis of various parameters for G-Channel color model. From this table, it is clear that value of error color for BPDHE is less as compared to the other techniques. It means that there is very little difference in the colors of the output image as compared to the input image even after enhancement. Even the value of CPSNR is more for BPDHE which is also desirable for any technique to work efficiently. More CPSNR means less noise entered during enhancement. In terms of entropy, the output entropy of R component is more as compared to input entropy in case of all the techniques except BBHE in which all component output entropy is less than input entropy and in case of BPDHE, in which output entropy of B component is also more. It means only R component show more details in the image after enhancement using G-Channel color model.



(a) HE Image (b) GC Image (c) BBHE Image



(d) BPDHE Image (e) RACE Approach

Fig. - 2: Images of "LANDSCAPE" after Equalization Using G-Channel of RGB Color Model

From the Fig. 2, it is clear that the visual quality of HE, GC, BPDHE and RACE approach is good and particularly only BPDHE is showing the best quality image in terms of color as the colors of the input and output image are almost same, while in others there is lot of variation in the color of the output image.

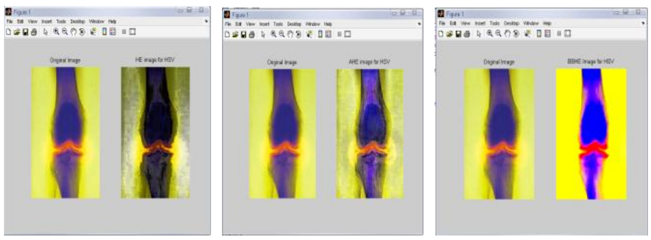
4.3 Results for HSV Color Model for 'Bonescan' Image

Table - 3: Results of Various Parameters for "BONESCAN" Image using HSV Color Model

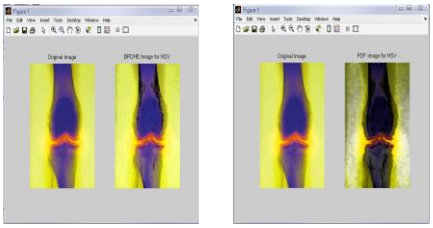
Parameter Vs Techniques	Error Color	CPSNR (dB)	Out Entropy		
			R	G	B
HE	0.1757	12.4926	7.6759	6.6663	7.1984
GC	0.0200	21.3532	7.3809	7.3478	7.3660
BBHE	0.2015	2.4323	2.4306	2.4611	2.6086
BPDHE	0.0008	25.1299	7.2345	6.7085	7.0175
RACE	0.1644	12.8430	7.7065	6.6823	7.2057

Input entropy of Bonescan Image: R=6.9825, G=6.6600, B=6.8148

In the Table 3, different techniques are compared on the basis of various parameters for HSV color model. From this table, it is clear that value of error color for BPDHE is less as compared to the other techniques. It means that there is very little difference in the colors of the output image as compared to the input image even after enhancement. Even the value of CPSNR is more for BPDHE which is also desirable for any technique to work efficiently. More CPSNR means less noise entered during enhancement. In terms of entropy, the output entropy of R, G and B components is more as compared to input entropy in case of all the techniques except BBHE in which all component output entropy is less than input entropy. It means all the components show more details in the image after enhancement using HSV Color model for medical image.



(a) HE Image (b) GC Image (c) BBHE Image



(d) BPDHE Image (e) RACE Approach

Fig. -3: Images of "BONESCAN" after Equalization Using HSV Color Model

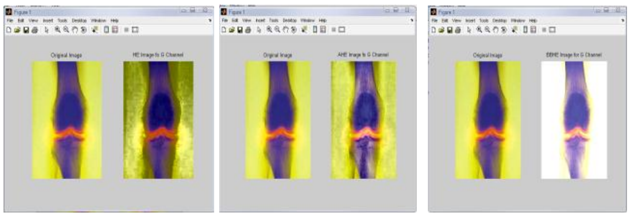
From the Fig. 3, it is clear that the visual quality of BPDHE is good as compared to the others. The results from BPDHE is showing the best quality image in terms of color as the colors of the input and output image are almost same, while in others there is lot of variation in the color of the output image.

4.4 Results for G-channel of RGB Color Model for 'Bonescan' Image

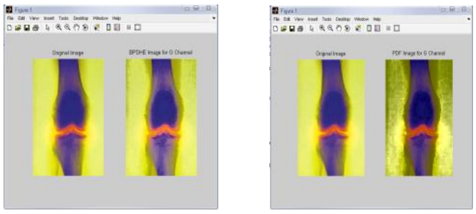
In the Table 4, different techniques are compared on the basis of various parameters for G-Channel color model. From this table, it is clear that value of error color for BPDHE is less as compared to the other techniques. It means that there is very little difference in the colors of the output image as compared to the input image even after enhancement. Even the value of CPSNR is more for BPDHE which is also desirable for any technique to work efficiently. More CPSNR means less noise entered during enhancement. In terms of entropy, the output entropy of component R is more as compared to input entropy in case of all the techniques except BBHE, in case of which all the output entropy values are less than input entropy values. Only in case of GC and BPDHE all components are having more value. It means only component R show more details in the image after enhancement using G-Channel Color model

Table -4: Results of Various Parameters for "BONESCAN" Image using G-Channel of RGB Color Model

Parameter Vs Techniques	Error Color	CPSNR (dB)	Out Entropy		
			R	G	B
HE	0.1605	13.9661	7.6853	6.3785	6.0567
GC	0.0079	21.6900	7.3583	7.3660	7.0666
BBHE	0.6726	2.6097	3.1047	3.0431	4.0653
BPDHE	0.0009158	25.5270	7.2895	6.7104	6.9729
RACE	0.1436	14.6066	7.6672	6.3425	6.1842



(a) HE Image (b) GC Image (c) BBHE Image



(d) BPDHE Image (e) RACE Approach

Fig. -4: Images of "BONESCAN" After Equalization Using G-Channel of RGB Color Model

From the Fig. 4, it is clear that the visual quality of BPDHE and GC is good as compared to the others. But, the results from BPDHE is showing the best quality image in terms of color as the colors of the input and output image are almost same, while in others there is lot of variation in the color of the output image.

4.5 Analysis of Computation Time of Image Enhancement Techniques for Color Images

Table -5: Computation Time for Color Images

ENHANCEMENT TECHNIQUES	Units of Time (Seconds)	
	HSV Model (512×512)	G-Channel RGB Model (512×512)
HE	3.375	2.953
GC	3.969	3.296
BBHE	11.219	5.422
BPDHE	12.141	5.828
RACE APPROACH	11.078	5.594

It is clear from the Table 5 that the HSV color model takes more time for processing than the G-Channel color model. This is because, for using HSV color model, first the RGB image is converted into HSV color model using large number of equations and then enhancement technique is applied on it. Then, after the completion of the enhancement technique HSV model is back converted into RGB color model. Thus, the processing time is more. But in case of G-Channel color model processing is directly done on RGB model. This is the reason that the processing time of HSV color model is more as compared to the G-Channel color model.

3. CONCLUSIONS

There are various techniques for enhancing the contrast of the digital image. After implementing some of these contrast enhancement techniques, it is concluded that the enhancement of different types of digital images is dependent on type of application. From the tables which are shown above, it is concluded that Brightness Preserving Dynamic Histogram Equalization is the most suitable technique in terms of Absolute Contrast Error or Error Color, Contrast Peak Signal to Noise Ratio (CPSNR). The visual quality of the images using BPDHE is good as compared to others with a limitation of high computation time for the implementation of BPDHE in comparison to all other techniques.

For color images, two different models are considered, they are HSV and G-Channel color model. All techniques are implemented on these two-color models. BPDHE technique provides good result both in terms of visual quality and objective performance parameters like Error Color and CPSNR. The computation time for implementing any technique in the case of G-Channel is less as compared to HSV color model. Hence, it is concluded that enhancement techniques are dependent on type of application.

In the future work, for the contrast enhancement purpose, more types of digital images can be taken from the different application fields, so that it becomes clearer that for which application which particular technique is preferred both for gray scale images as well as color images. More new parameters can also be considered for the evaluation of enhancement techniques. New other color models can also be chosen for better comparison purpose and also optimization techniques can be utilized to lower the complexity.

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