RESEARCH ARTICLE

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Comparative Analysis of Image Enhancement Algorithms

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Abstract

In the complex instruments utilised in essential fields such as satellite cameras, CT scanners, and High-Resolution Cameras (Underwater), image capture is critical without human-rated aberrations, sounds, or atmospheric disturbances. Even full reference QA (quality assessment) approaches have a limited ability to predict quality accurately. As a result, the difficulty of evaluating and enhancing photographs is further subdivided into domain-specific issues by focusing on a small set of artefacts. The most popular is entropy, which is usually relevant in picture coding: it is a lower limit for the average coding length in bits per pixel that may be attained without any loss of information by an optimal coding scheme. The word 'specific' is significant because it establishes right away that the strategies covered in this paper are primarily problem-solving techniques. For example, a procedure that works well for improving X-ray images may not be the ideal option. Thus, a method that works well for boosting X-ray photos may not be the greatest option for enhancing photographs obtained by a satellite thousands of miles away from the Earth. Image enhancement algorithms proposed in this paper are Intensity-Hue-Saturation transformation, Histogram Equalization algorithms, Edge Detection techniques and Retinex theory algorithms. These algorithms are implemented under satellite imagery, medical scans, underwater images, and their parameter analysis.

Keywords: Edge detection, Entropy, Histogram equalization, Image enhancement, Retinex algorithm.

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Introduction

Image enhancement is considered one of the most predominant techniques in the field of image research. Image enhancement's main goal is to improve an image's quality and visual appearance or offer a better transform representation for future automated image processing. Images captured in medical scans, satellite, and real-life photographs suffer from poor and bad contrast and unwanted noise. It is essential to increase contrast and reduce noise to improve image quality.[1] Image Enhancement Techniques are one of the most important steps in detecting and interpreting medical pictures. It enhances visual clarity for human sight by eliminating blurring and noise, boosting contrast, and revealing details. These are examples of enhancement operations. Depending on the goal, the improvement technique differs from one field to another. There are two types of picture enhancement techniques available: spatial domain and frequency domain enhancement. We offer an overview of Image Enhancement Processing Techniques in the Spatial Domain in this study. More particular, we classify processing methods based on representative image enhancement techniques. As a result, this paper's contribution is to classify and review Image Enhancement Processing Techniques. This is determined by comparing the several parameter values obtained. It will be functional and easier to detect the enhancing techniques for future research.

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Algorithms and Working

Intensity-Hue-Saturation (IHS)

IHS scheme is an alternate approach to RGB color scheme. It presents colors more nearly to the IHS Transformation human who perceives the image. Low saturation indicates impure color, and high saturation indicates pure and intense color. Usually, RGB images lack saturation even after being contrast stretched. To overcome this, the IHS transformation of RGB image is done with equalization on components of IHS image and transformed back to IHS and then into the RGB system for better visualization.[2]

Brightness Preserving Bi-Histogram Equalization (BBHE) and Dualistic Sub-Image Histogram Equalization (DSIHE)

A 'Histogram' represents the frequency of occurrence of all gray-levels of an image. In the area of contrast enhancement in an image, Histogram Equalization (HE)[3-5] is one of the most common methods used as it distributes the pixel intensity over full intensity range. But this technique is not useful for the brightness preservation of an image. To overcome this, the BBHE method was proposed by Yeong-Taeg Kim in 1997.[6]

BBHE

The Brightness Preserving Bi-Histogram Equalization (BBHE) algorithm aims to decompose an image into two sub-images based on their mean gray levels. The resulting images have intensity ranging from minimum to mean gray value and from mean to the maximum. These images are histogram equalized and then combined to get the resultant image.

DSIHE

The Dualistic Sub-Image Histogram Equalization (DSIHE), introduced by Yu Wan, Qian Chen and Bio-Min Zang is similar to the BBHE algorithm. This algorithm divides the image into two sub-images based on median of gray levels. Thus, we have one bright and one dark image. This algorithm aims to increase Shannon's Entropy of the image. HE is applied to the decomposed images and then combined to get the output.[5,6]

Edge Detection

Edge detection[7,8] is used to find the discontinuous points in an image. Points where image brightness varies by a large margin are called edges. Edge detection works while preserving the structural image properties and reduces the amount of data in an image. Different filters are used in edge detection algorithms. Prewitt edge detection is used for detecting horizontal and vertical edges in an image. Sobel edge detection reduces noise and emphasizes on the center of an image. Canny edge detection is the most frequently used method. It converts an image to grayscale, reduces noise and detects the edges.

Retinex Theory

Edwin Land composed the Retinex Theory.[10-12] The word 'Retinex' was derived from two words – Retina + Cortex. This theory states that the way we perceive the colours of the objects around us results from the light incident around it and the wavelength of light that the object reflects, which enters our eyes. Thus, this theory aims to divide an image into two sub-images: Brightness Image and Reflection Image, and then remove the Brightness Component from the Original Image so that the true attributes of an object are retained.

Single Scale Retinex (SSR)

Algorithm:

- The original image is read, and the numerical matrix of each channel from RGB is taken and converted into double type.
- Each channel is then passed through a Gauss template.
- The logarithm of the original image and the Gaussian convoluted image is taken and then the Convoluted Image is subtracted.
- The image of each channel is given a linear stretch and the final RGB image is combined.[12]

Multi-Scale Retinex (MSR)

As the SSR algorithm has issues with color fidelity and the choice of scale is a very important factor, the MSR algorithm comes into use as it applies the Gauss filter on multiple scales. The MSR output weighs the different scales of SSR and adds them together.[12]

Multi-Scale Retinex with Colour Recovery (MSRCR)

The algorithms mentioned above lead to the dominance of a certain color from the RGB, leading to the formation of grayish images. Thus, the MSRCR algorithm comes with a color recovery step, which multiplies the output of MSR with a color recovery factor C.[12]

Parameters Calculated

i. *Entropy:* In the context of image processing, it can be defined as the lower limit for the average coding length in bits per pixel, realized by a coding scheme without loss of information.[12]

$$Entropy = -\sum_{i=0}^{n-1} p_i log_2 p_i \tag{1}$$

n = no. of gray levels (256 for 8-bit images)

pi = probability of gray level of pixel

ii. *Standard Deviation:* The standard deviation measures the amount of variation or dispersion of a set of values. High standard deviation indicates that values are spread out, and low means values are close to the measurement.[3]

$$\sigma = \sqrt{\frac{\Sigma(x_i - \mu)^2}{N}} \tag{2}$$

σ = population standard evaluation

N = size of population

x_i = each value from the population

μ = the population mean

iii. *NIQE:* It is natural image quality evaluator. It does not compare the image to some other image given by the user as an input, but it compares the image to default model computed from natural scenes. Lesser the NIQE score, better the perceptual quality.[12]

iv. Peak Signal to Noise Ratio (PSNR): PSNR can be defined as the ratio of maximum power of an image and the noise present in it that corrupts its visual quality.[5]

$$PSNR = 10log_{10}\left(\frac{(L-1)^2}{MSE}\right) = 20log_{10}\left(\frac{L-1}{RMSE}\right) \quad (3)$$

L = number of maximum possible intensity levels in an image

RMSE = Root Mean Square Error

v. Absolute Mean Brightness Error (AMBE): It is defined as the difference between the mean of two images. This parameter shows the amount of brightness preserved after processing an image.[5]

$$AMBE = E(X) - E(Y) \quad (4)$$

E(X) = Mean of the input image

E(Y) = Mean of output image

vi. Structural Similarity Index (SSI): The SSI denotes the degradation of quality in an image after enhancement. It shows how similar the output image is to the input image. These values generally lie between 0 and 1. If the value is 1, it means the output is exactly equal to the input.[5]

vii. Contrast: It measures the intensity contrast between a pixel and its neighbour over the whole image.[13]

$$\sum_{i,j} |i-j|^2 p(i,j) \quad (5)$$

viii.Energy: It measures the localized[13] change of an image or the rate of change of colour/brightness/magnitude of pixels over local areas.

$$\sum_{i,j} p(i,j)^2 \quad (6)$$

ix.Homogeneity: Defined as the closeness of the distribution of elements in the image matrix.[13]

$$\sum_{i,j} \frac{p(i,j)}{1+|i-j|} \quad (7)$$

Results and Discussion

Intensity-Hue-Saturation (IHS) Transformation

Figure 1: Difference in the image after applying IHS transformation

Table 1: Comparison of various parameters for ihs transformation

Sr. No.	*Parameters*	*Input Image*	*Output Image*
1	NIQE	5.796	5.239
2	Entropy	7.671	7.8942
3	Standard Deviation	57.795	0.28661

BBHE and DSIHE Algorithms

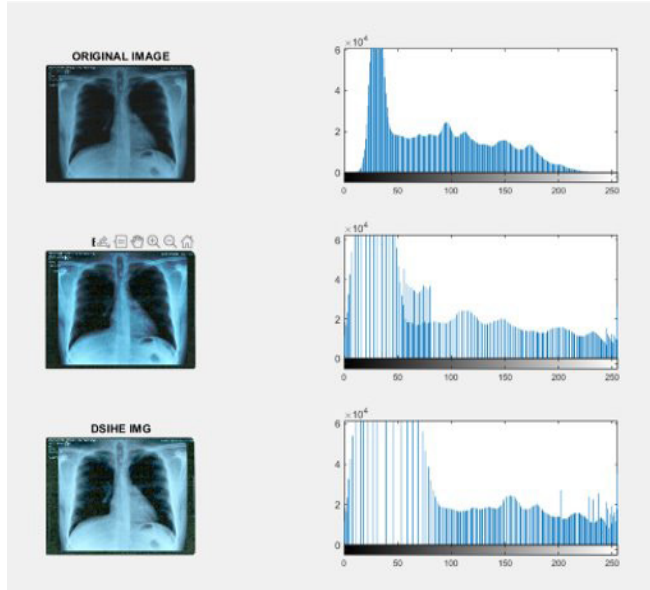

Figure 2: Image and histogram comparison for BBHE and DSIHE

Table 2: Parameter comparison for BBHE and DSIHE

Sr. No.	*Parameters*	*Input Image*	*Output Image*
1	PSNR	18.8443	14.2842
2	AMBE	17.8142	41.0679
3	SSIMVAL	0.82051	0.72297

Edge Detection

Figure 3: Input image

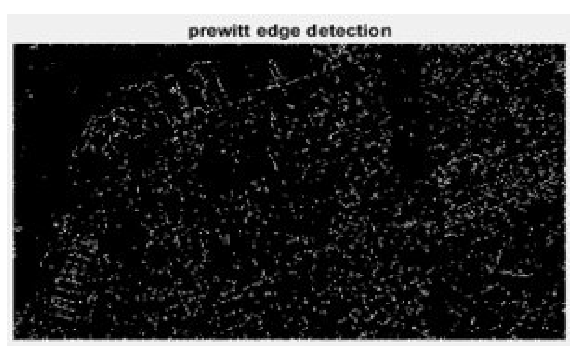

Figure 4: Image after applying prewitt edge detection

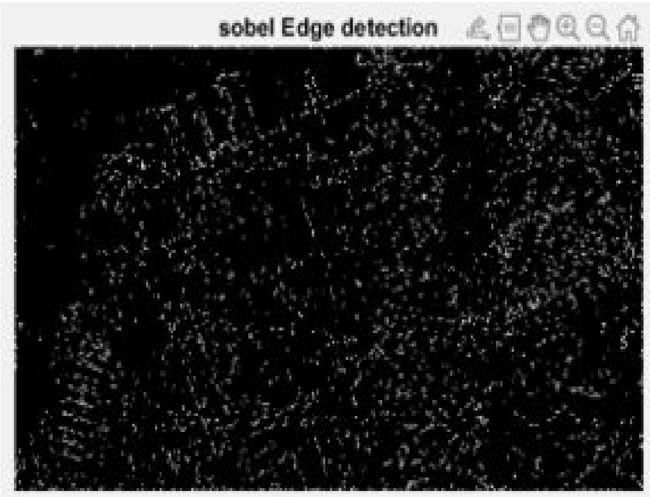

Figure 5: Image after applying Sobel edge Detection

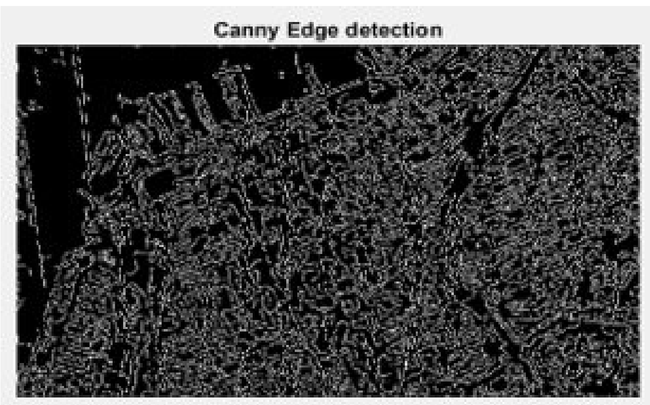

Figure 6: Image after applying Canny edge Detection

Table 3: Parameter comparison for canny, sobel and prewitt edge detection

Sr. No.	*Parameters*	*Input Image*	*Sobel*	*Canny*	*Prewitt*
1	Contrast	1.6113	0.05382	0.17753	0.05151
2	Homogeneity	0.65756	0.97309	0.91124	0.97425
3	Energy	0.05528	0.88077	0.59086	0.83361

Single-Scale Retinex (SSR)

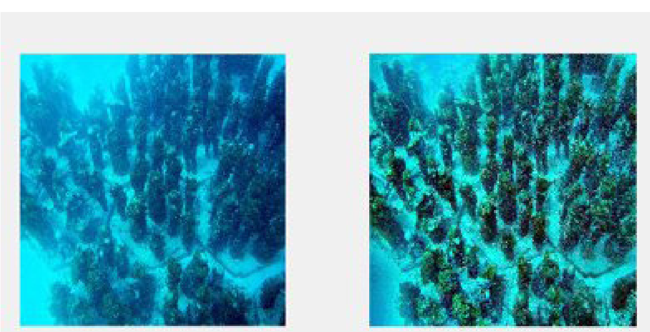

Figure 7:. Difference in image after applying SSR algorithm

Table 4: Parameter comparison for SSR

Sr. No.	*Parameters*	*Input Image*	*Output Image*
1	NIQE	3.5614	4.9044
2	Entropy	7.1271	7.328

Figure 8: Difference in image after applying SSR algorithm

Table 5: Parameter comparison for SSR

Sr. No.	*Parameters*	*Input Image*	*Output Image*
1	NIQE	3.039	3.2322
2	Entropy	7.0183	7.6386

Multi-Scale Retinex with Colour Recovery

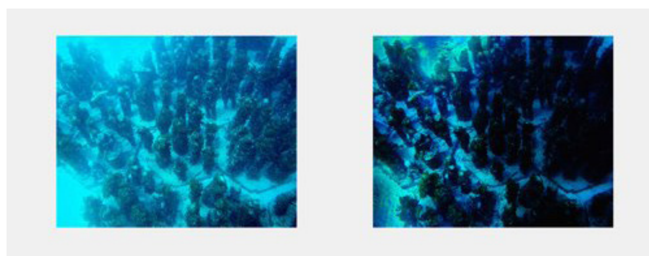

Figure 9: Difference in image after applying MSR-CR algorithm

Table 6: Parameter comparison for MSR-CR

Sr. No.	*Parameters*	*Input Image*	*Output Image*
1	NIQE	3.5614	3.617
2	Entropy	7.1271	5.3486

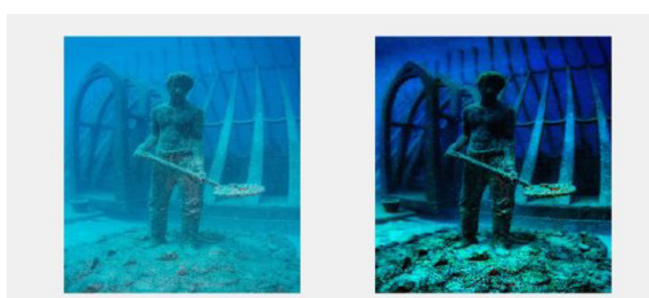

Figure 10: Difference in image after applying MSR-CR algorithm

Table 7: Parameter Comparison For MSR-CR

Sr. No.	*Parameters*	*Input Image*	*Output Image*
1	NIQE	3.039	2.9429
2	Entropy	7.0183	6.1454

After applying IHS transformation to the satellite image and by looking at changes in the input image of Figure 1[14] and Table 1 parameters, it was observed that entropy of the image increases followed by a significant decrease in standard deviation which implies that the pixel intensities of the transformed image are closer to the mean. This also shows that IHS transformation increases information inside the image. Histogram Equalisation (HE) is said to increase the contrast in the low contrast regions of an image. Observation of Figure. 2[15] for both the cases display a fairly stretched histogram of the input image. Table 2 shows that Peak Signal-to-Noise Ratio and the Structural Similarity Index of the Brightness preserving Bi-Histogram Equalisation (BBHE) algorithm is better compared to Dualistic Sub Image Histogram Equalisation (DSIHE). Also, the Absolute Mean Brightness Error (AMBE) of BBHE is lesser which indicates that more brightness is preserved. Through observation of change in input image in Figure 3[16] after applying Prewitt (Figure 4), Sobel (Figure 5) and Canny (Figure 6) operators along with changes in parameters in Table 3, it can be concluded that there is equal distribution of pixel intensities in the Canny operator, which is why it's Energy is comparatively less than the Sobel and Prewitt operator. The Canny operator also preserves the contrast of the image more than that of other operators. Single Scale Retinex (SSR) algorithm enhances the Natural Image Quality Evaluator (NIQE) and Entropy of Input Images of Figure 7[17] and Figure 8,[18] but there exists one drawback. SSR algorithm applies Gauus filter on a single scale, which can lead to dominance of a certain colour over the others from the R-G-B components, resulting in unequal distribution of gray levels in the image. The parameter changes due to SSR algorithm is shown in Table 4 and Table 5. This also occurs in the Multi-Scale Retinex (MSR) algorithm. According to the parameter changes observed in Table 6 and Table 7 after applying the Multi-Scale Retinex with Colour Recovery (MSR-CR) to input images of Figure 9[17] and Figure 10,[18] there is a slight decrease in Entropy and the NIQE, but it improves the overall visual quality of the image. The results acquired in all the above-mentioned tables are genuine and authentic.

Conclusion

This paper applied various image enhancement techniques to multiple applications on images from different domains. Parameters that specify the quality of an image were used to compare the efficiency of these algorithms. The study authenticates the Canny Edge Detection, the Retinex algorithms and BBHE techniques. These techniques can be recommended for further intricate computer analysis and human interpretability. Although these can be categorized as the most efficient image enhancement techniques today, there is an immense potential to develop these techniques further.

References

[1] Ačkar, Haris & Almisreb, Ali & Saleh, Mohd.A.. (2019). A Review on Image Enhancement Techniques. *Southeast Europe Journal of Soft Computing*. 8. 10.21533/scjournal. v8i1.175.

[2] Stuti Ahuja, Seema Biday. (2013). A Survey of Satellite Image Enhancement Techniques. IJAIR (2278-7844)/ vol 2, Issue 8, pp. 131-136.

[3] Salem, Nema & Malik, Hebatullah & Shams, Asmaa. (2019). Medical image enhancement based on histogram algorithms. *Procedia Computer Science, 163*, 300-311.

[4] Kaur H., Rani J. (2016). MRI brain image enhancement using Histogram Equalization techniques. *International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 2016, pp. 770-773.

[5] Patel, Omprakash & Maravi, Yogendra & Sharma, Sanjeev. (2013). A Comparative Study of Histogram Equalization Based Image Enhancement Techniques for Brightness Preservation and Contrast Enhancement. *Signal & Image Processing: An International Journal*. 4. 10.5121/sipij.2013.4502.

[6] Rasna, V.K. (2016). Study of Brightness Preservation Histogram Equalization Techniques. *IOSR Journal of Electronics and Communication Engineering, 01*, 66-70.

[7] Ansari, Mohd & Kurchaniya, Diksha & Dixit, Manish. (2017). A Comprehensive Analysis of Image Edge Detection Techniques. *International Journal of Multimedia and Ubiquitous Engineering*. 12. 1-12. 10.14257/ijmue.2017.12.11.01.

[8] P. Ganesan and G. Sajiv. (2017). A comprehensive study of edge detection for image processing applications. *International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*. pp. 1-6, doi: 10.1109/ICIIECS.2017.8275968.

[9] Hussein, Ruaa & Hamodi, Yaser & Sabri, Rooa. (2019). Retinex theory for color image enhancement: *A systematic review. International Journal of Electrical and Computer Engineering (IJECE)*. 9. 5560. 10.11591/ijece.v9i6.pp5560-5569.

[10] Tang, Ling & Chen, Shunling & Liu, Weijun & Li, Yonghong. (2011). Improved Retinex Image Enhancement Algorithm. *Procedia Environmental Sciences, 11*, 208–212. 10.1016/j.proenv.2011.12.032.

[11] Li, Yujie & Li, Jianru & Li, Yun & Kim, Hyoungseop & Serikawa, Seiichi. (2019). Low-Light Underwater Image Enhancement for Deep-Sea Tripod. IEEE Access.

[12] Hu K, Zhang Y, Lu F, Deng Z, Liu Y. (2020). An Underwater Image Enhancement Algorithm Based on MSR Parameter Optimization. *Journal of Marine Science and Engineering*, 8(10):741. https://doi.org/10.3390/jmse8100741

[13] Sivakamasundari J., Kavitha G., Natarajan V. and Ramakrishnan S. (2014). Proposal of a Content Based retinal Image Retrieval system using Kirsch template-based edge detection. *2014 International Conference on Informatics, Electronics & Vision (ICIEV)*, pp. 1-5, doi: 10.1109/ICIEV.2014.6850744.

[14] https://svs.gsfc.nasa.gov/vis/a000000/a002600/a002640/

[15] https://informaconnect.com/the-science-behind-x-ray-imaging/

[16] https://www.satcen.europa.eu/page/sar_course_sar_

[17] https://blogs.umb.edu/buildingtheworld/category/the-snowy-mountains-hydroelectric-power-project-australia/

[18] https://www.scubadiving.com/are-artificial-reef-exhibits-new-era-scuba-diving-underwater-art-museums