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A comparative Study of Image Enhancement Techniques for Natural Images

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ABSTRACT

Enhancement is most interesting parts in image processing field. It uses to enhance the structural appearance for picture without the degradation in the original input image. The enhancement techniques become the important key and simply extraction features by removing noise and another items inside an image. Several enhancement techniques have achieved with different and inaccurate results. The aim of this paper, the nature images quality was improved by the many enhancement techniques like of Histogram Equalization (HE), Local Histogram Equalization (LHE), Adaptive Histogram Equalization (AHE), Contrast Limited Adaptive Histogram Equalization (CLAHE), Brightness Preserving Bi-Histogram Equalization (BBHE), Dualistic Sub-Image Histogram Equalization (DSIHE) and Recursive sub-image histogram equalization (RSIHE). In evaluation step, the performance of all these techniques are examined by values measurements of SSIM (Structural Similarity Index Matrix), Entropy, Peak Signal-to-Noise Ratio (PSNR) and Signal to Noise Ratio (SNR). The comparisons of the better existing results are given because to explain the best possible technique that can be used as suitable image enhancement. The results of the enhanced of 15 nature images have showed DSIHE technique has a batter a values of SSIM and Entropy with 0.9885 and 59975 respectively. Overall, based on the PSNR and SNR values, the CLAHE technique are recorded values higher than of other six techniques in 21.2952 and 192932 values.

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1. Introduction

Image enhancement shows primary task which used by image processing uses. It used by experts to make decisions with respect to the image material. Style of image enhancement contain noise reduction, edge enhancement and contrast enhancement (Qi et al., 2022). The improving of stored image power may be need to using enhancement techniques. These techniques have used to increase or decrease contrast to gives an image lighter or darker. In addition, image enhancement has used for improving the information's sensitivity inside images used to human watchers or to suggest enhanced input for further fixed image processing techniques. The goal of image enhancement is to improve the exploitability or perception of information inside images for human watchers, and to deliver improved input for other robotic techniques which are more useful used in image processing (Wang et al., 2021).

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Therefore, the color image enhancement is one of the most visually appealing applications of digital image processing. This technique has been effective vision system for agriculture domain. Color image enhancement is the modification of an image to alter impact on the viewer (L. Zhang et al., 2021). In image enhancement the goal is to accentuate certain image features for subsequent analysis or for image display. An evaluation studying has applied by (Singh & Mittal, 2014) on seven enhancement techniques. A fifteen images in agriculture field which are captured by digital camera have been used as dataset. The results comparative study are explained by tables which are viewing the values of produced images after the spatial techniques and measures of enhancement are achieved. The rest of the paper has been ordered for describing diffident several enhancement techniques. An evaluation parameters have explained to evaluate all seven techniques. The results showed that CLAHE technique has batter values of PSNR and SNR when it compared with rest techniques (Firoz et al., 2016). In this paper, we have considered a different seven enhancement techniques on real nature images as new dataset. We have also experimented on the best techniques taken, based on several evaluation measures such as SSIM, Entropy, PSNR, and SNR.

2. Related works

Various literature are available for enhancement of images in recent trends. Histogram equalization method is used particularly to enhancement for grey level image as well as colored images. The author proposed a direct 3D histogram equalization method by which it gives out a uniform histogram of the colored values (Patel & Bhandari, 2019). Many researchers have works on color denoising to improve the color image visibility, as author work on the color image enhancement via chroma diffusion. In segmentation it is quite useful as coupling of chromacity and brightness in color images. Many methods fond to be most suitable to different test images for enhancement of low contrast and low intensity color images and it was found by the authors that index of fuzziness and the 'entropy' decreases with enhancement (Butola, Pratik, & Kumar, 2015) . As soon as technology grows on, many techniques have been arrived by many researchers to recount the research for capturing real life sections, authors includes different alterations of the original approach by involving different current models for human vision and range mapping uses (Agrawal, Chourasia, Kapoor, & Agrawal, 2014).

In another paper author proposed a Gaussian membership function to fuzzy the image information in spatial domain. For the desired appearance of images author express fuzzy contrast-based quality operator and entropy-based quality operator and the matching visual operators, which is most fitted for under exposed images (Nayak & Ystem, 2016). Many work has been carried out in the field of image processing for the sake of enhancement for color images to improve the quality and visibility of the images. It shows the study of different techniques used for image enhancement by utilizing different areas. It also displayed the limitation of the methods used for enhancement: author Zhu Ronga, Zhu Lib, Li Dong-nan, used the histogram equalization technique on colored image to improve the contrast of the color heritage Image and try to give the dramatic improvement in Image and its structural details. There is not much improvement have been done for different images.

Different authors have given their different approaches to make enhancement in color images on domains by using different area of specialization like artificial intelligence, neural networks vice versa. They perform a comparative papers which analysis a fundus image enhancement techniques to discover diabetic retinopathy (DR) (Rasti et al., 2016). The comparative performance and evaluation of these several enhancement techniques will supporting the selecting best and appropriate technique that may much develop the detection of diabetic retinopathy. It was observed that sub-image histogram equalization (ESIHE) had better results from other techniques.

A comparative study for several histogram equalization techniques is effectively achieved for analyzing and diagnosing diseases. The histogram processing which has been used to diagnosing tumors exactly in brain and cancer (Nagaiah, Manjunathachari2 2015). The main goal of all techniques is to enhance the brightness and contrast of the input image. It found that DSIHE and RSIHE which are the developed version of BBHE provide better results that be utilized in the medical images enhancement for better analysis. In addition, (Liang et al., 2021)showed a comparative study on various enhanced techniques like histogram equalization (HE), adaptive histogram equalization (AHE) and contrast-limited adaptive histogram equalization (CLAHE). It was noted that AHE has produced a best values according to entropy and SNR for output images as enhancement results.

0 have applied state-of-art image enhancement techniques, such as ACE, CLAHE, LAB and SP algorithms, to improve the quality of underwater images affected by low contrast, poor visibility conditions, not uniform lighting, color variations, noise and blur effect (Yang, Jin, Jia, Xu, & Chen, 2022). The results have been evaluated through

quantitative metrics, like average luminance, information entropy, and average gradient of image. Highest score in image quality assessment is obtained from the histogram equalization (CLAHE) technique

3. Image enhancement techniques

There are several and different techniques which make enhancement in a digital image without degrading it. The enhancement techniques can widely categorized in to the next two types: 1. Spatial Domain Methods 2. Frequency Domain Methods. In spatial domain techniques, it immediately deals with the pixels inside image (Sharma, Agrawal, & Munjal, 2022) and the pixel values are used to apply desired enhancement. Therefore, frequency domain is firstly used to transfer image for frequency. Equalization is a technique used for image enhancement that allocates with image histogram that is consider plot number for pixels in every intensity values. As mentioned above, the technique balances the pixels in the input image for every gray level to provide a good resolution. histogram equalization is a famous spatial domain enhancement technique because of its robust performance and simple technique in several types of images (Maithri, Dharshini & Vaishnavi , 2022). It is has a several types of techniques:

3.1 Typical histogram equalization (HE)

HE is essentially, the mapping of every pixel of the input image to the relating pixels of the produced image. HE matches the intensity values to full range of the histogram to give an enhanced produced image. It enhances the contrast and brightness of the input image via growing the levels values of every pixel getting growth for dynamic scope extension (Sahooa & Lakshmi, 2021)(SatyasangramSahooa & Dr. R. Lakshmi, 2021).

3.2 Local histogram equalization (LHE)

LHE performs a block-overlapped technique that consider a sub block application to enhance the image. Next, the center pixel value is calculated of sub block. The sub block is shifted one by one pixel and repeated to get the batter output image(Li, Dong, & Jiao, 2015). A local change function for every pixel is calculated based on its neighboring pixels. A little window is specified for the Contextual Region (CR) of that sub block for the center pixel. Pixels reducing in that window are considered for CDF calculation. Transform function differences and accept to CR because of CDF adjusts as the window slides. LHE offers useful contrast enhancement that can always be looked over enhancement that is the limitation of this technique. LHE technique is difficult than other techniques as for each image pixel, local histogram is made and handled (Iqbal et al., 2021).

3.3 Adaptive histogram equalization (AHE)

AHE utilized to progress contrast in image and consider an important computer image processing technique because of its adaptive type. It calculates different histogram of image and utilizes them to modify the intensity values of image(Yadav, Kumar, Kumar, & Gupta, 2017). AHE is more suitable for improving regional contrast and edge enhancement in every region of the image. Therefore, it has large leaning to over-expand the noise in moderately and homogeneous regions of the image. This challenge was removed by contrast limited adaptive equalization(Shaikh & Sayyad, 2014).

3.4 Contrast-limited adaptive histogram equalization (CLAHE)

CLAHE is a diffident of AHE which used for lower contrast extension in homogenous region of images as regular. The contract extension in the area of a shown pixel value is shown by the drop of the change (Sankpal & Deshpande, 2016). This is proportional to the slope of the neighborhood cumulative distribution function CDF and therefore to the value of the histogram at that pixel value. At predefined value that produced by CDF, it using to histogram cutting step. The histogram has been limited the amplification CLAHE technique (Rani, 2014).

3.5 Brightness Preserving Bi-Histogram Equalization (BBHE)

It is mainly the new version of regular HE which major purpose is to preserve rightness and avoid false coloring. This technique divides the input image histogram into two subparts (Shaker, Baker, & Mahmood, 2022). The division is achieved by the average intensity of all the pixels that is to be the input mean brightness value of all pixels which current in the input image. After the partition step using mean, these two histograms are equalized independently using the typical histogram equalization technique. When implement this phase, it showed that the resultant image, mean brightness is current properly between the input mean and the middle gray level. Finally, the two equalized images has been linked to produce the output image (AbdulSaleem & Abdul Razak, 2014).

3.6 Dualistic Sub-Image Histogram Equalization (DSIHE)

DSIHE technique works by the similar approach which used in BBHE technique. The histogram of input image is decomposed into two portions (G. Kaur & Kaur, 2016). The changes is it makes median under consideration to divide the image being one bright and one dark. In other words, DSIHE technique separates the image on the origin of gray level values, with 0.5 as the increasing distribution value. HE is achieved to the decomposed sub-images. These sub-images are merged to output the DSIHE output image.

3.7 Recursive Sub-Image Histogram Equalization (RSIHE)

The global type of DSIHE is RSIHE technique. This technique splits the histogram of input image into sub-histograms by Cumulative Density Function (CDF).The image is recursively separated into equal parts for number of recursion levels using the CDF value match to level 0.5. The sections will take a pixels in same and equal according of its number(Bora, 2017).Scalable brightness preservation is applied using this recursive process. RSIHE, histogram has been separated the by median estimation of brightness instead of using input mean brightness. The main purpose presently is to discover the best appreciation of iteration element to find vast enhancement results. On other hand, technique can support procedure of adapting the level for development (S. Kaur, 2015).

4. Evaluation of enhancement techniques

The comparison of various image enhancement techniques is achieved in objective type for color images. Quantitative performance measures are very vital in comparing different image enhancement techniques (Qureshi, Deriche, Beghdadi, & Mohandes, 2015). Also, the visual results for evaluation include Structural Similarity Index Matrix (SSIM), Entropy, PSNR and SNR respectively. The several evaluation parameters using for measure the performance of techniques and which one is better for enhancement.

4.1 Structural similarity index matrix (SSIM)

Structural Similarity Index Matrix (SSIM) is a process for perception based on model. In this process, image degradation is considered as the change of observation in structural information. Besides that, it cooperates certain another principal observation based fact like luminance masking, contrast masking, etc(Q. Zhang, Li, & Deng, 2018). The term structural information confirms about the strongly inter-dependant pixels or spatially closed pixels. These toughly inter-dependent pixels refer to some more principal information about the visual things in image domain. Luminance masking is a name which the part of distortion of an image is less visible in the edges of an image. Instead, contrast masking is a term where distortions are too less visible in the texture of an image(Roy, kumar Jain, Lal, & Kini, 2018). The SSIM guesses a perceived quality of images and videos. It calculates the matching which consider an important measures for evaluation that used between two images: the input and the improved image. Finally, SSIM process has showed by below three terms:

$$SSIM(x,y) = [l(x,y)]^{\alpha} \cdot [c(x,y)]^{\beta} \cdot [s(x,y)]^{\gamma}$$

Where , l is the luminance (used to compare the brightness between two images), c is the contrast (used to differ the ranges between the brightest and darkest region of two images) and s is the structure (used to compare the local luminance pattern between two images to find the similarity and dissimilarity of the images) and α, β and γ are the positive constants (Silva, Yeh, Zhu, Batista, & Keogh, 2019) Again luminance, contrast and structure of an image can be extracted separately as:

$$I(x,y) = \frac{2\text{uz}uy + C1}{\text{u2x} + \text{u2y} + \text{C1}} \quad (1)$$

$$c(x,y) = \frac{2\text{Q}xQy + C2}{\text{Q2x} + \text{Q2y} + \text{C2}} \quad (2)$$

$$s(x,y) = \frac{\text{Qxy} + C3}{\text{QxQy} + \text{C3}} \quad (3)$$

Where µxµx and µyµy are the local means, σxσx and σyσy are the normal variations with σxyσxy is the cross-covariance of images x and y sequentially. If α=β=γ=1α=β=γ=1, next the index is simple as the following form using below Equations:

$$SSIM(x,y) = \frac{(\text{2uxuy} + \text{C1})(\text{2QxQy} + \text{C2})}{(\text{U2x} + \text{U2y} + \text{C1})(\text{Q2x} + \text{Qy2} + \text{C2})} \quad (4)$$

4.2 Entropy

It is one of famous and important parameter to measure for image quality. It also uses to know the information content and its average. A high and large values of entropy leads to batter and suitable results and more information content inside images(Lee, Cho, & Kim, 2019)

$$\text{ENTi} = -\sum_{1=0}^{L-1} 1(1) log1 \quad (5)$$

The ENT (i) symbolizes to entropy, I(l) referred to possibility density function of image which have (l) intensity level and (L) number referred for gray levels.

4.3 Peak signal-to-noise ratio (PSNR)

It is one of main parameter which used to measure the image quality after enhancement. It presents the peak error for the output and produced image. The value of this parameter must be large to produce a good and better results. It denotes the ratio of signal power-to-noise power and noise power should be minimum in batter results. It has denoted below as:(Firman Ashari, 2021)

$$\text{PSNR} = 20\log_{10} = \left(\frac{255}{\text{MSE}}\right) \quad (6)$$

4.4 Signal to noise ratio (SNR)

SNR is identified as Signal Power to Noise Power which mean a higher value of SNR is always selected since it shows larger quantity of signal content than the noise content in the signal, equation below shows the SNR parameters (Rasheed et al., 2021):

$$SNR = 20 * Log10 \frac{\text{A signal}}{\text{A nosie}} \quad (7)$$

$$SNR = 10 * Log10 \frac{A\ signal}{A\ nosie} \quad (8)$$

5-Methodoloy

This section shows the practically steps which achieved to product the results. Fifteen images as dataset have taken by digital camera with high resolution. Preprocessing steps have achieved on input images for resize the image dimensions to be an equal size in (500 * 500) pixels for all dataset by MATLAB. In addition, all five enhancement techniques have applied on images to outing the enhanced image to evaluating step. The SSIM, Entropy, PSNR and SNR are used as evaluation measures to compare among techniques to choose the highest factors as a better results. Fig.1. shows the methodology of paper

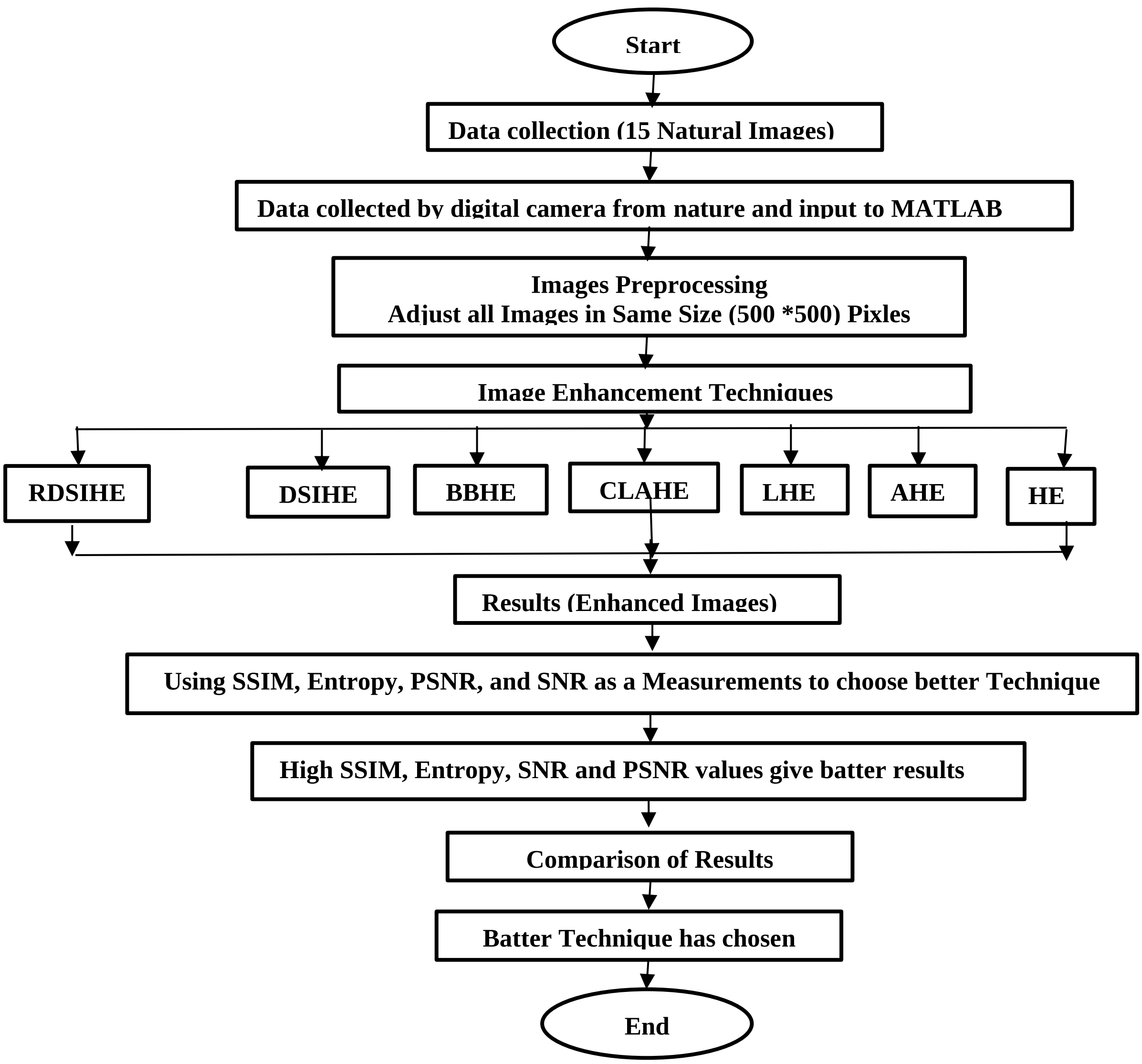

Fig. 1 – flow chart of methodology

6. Discussion and Results

This section discusses the results obtained from the series of experiments conducted. The objective of the undertaken experiments is to determine suitable enhanced techniques for taken fifteen test nature images as database. The techniques which achieves are HE, LHE, AHE. BBHE, DSIHE, RMSHE and RSIHE respectively. Illustration in Fig.2. Shows samples of original images which taken from real nature. The comparison and simulation of various s techniques and all enhanced images applied by MATLAB R2020a and using modern software processing and window version 10.

Fig. 2 – samples of dataset images.

Depending on numerical examples which shown in Table 1 all seven enhancement techniques have produce different values of SSIM for the all images in dataset. As seen in the table below the DSIHE technique have produced the batter values of all dataset images. Fig. 3. Shows that the DSIHE technique has produced an important enhancement to the resultant images. Therefore, same pattern is also found for entropy and it depicted in Table 2 and Fig.4. the DSIHE technique has again produced the highest values of all 15 images when it compared with other seven techniques respectively.
However, the result of CLAHE Table 1 and Table 2 show good results enhancement, and they also produced batter and highest PSNR and SNR values for the all input images. Moreover, the enhancement made by DSIHE technique is very important enough. Fig.5 and Fig.6 present the PSNR and SNR values for all techniques. Finally, several simple of enhanced images by all seven technique have showed in Fig.7.

Table 1 – Values of SSIM.

ImNo	HE	AHE	LHE	CLAHE	BBHE	DSIHE	RDSIHE
1	0.5930	0.5853	0.5150	0.5824	0.5881	0.7935	0.5098
2	0.5541	0.5474	0.4637	0.5449	0.5559	0.7559	0.5322
3	0.6142	0.6109	0.4889	0.5942	0.6142	0.8129	0.5109
4	0.5887	0.5671	0.4984	0.5635	0.5879	0.7890	0.5098
5	0.6060	0.5803	0.4871	0.5771	0.6035	0.7042	0.5441
6	0.6130	0.5944	0.5056	0.5902	0.6070	0.8110	0.6091
7	0.6220	0.6118	0.5286	0.6047	0.6159	0.8226	0.5726
8	0.6221	0.6096	0.4957	0.6089	0.6204	0.8202	0.5731
9	0.5647	0.5499	0.4647	0.5476	0.5633	0.7629	0.5101
10	0.8073	0.7903	0.6758	0.7766	0.8061	0.8055	0.5755
11	0.6182	0.6981	0.6445	0.6893	0.7215	0.9885	0.6855
12	0.6163	0.6099	0.5764	0.6386	0.6243	0.8755	0.6112
13	0.5102	0.6543	0.4345	0.5432	0.5432	0.8443	0.5096
14	0.5512	0.5643	0.5637	0.5043	0.5621	0.8901	0.5332
15	0.6713	0.6005	0.6002	0.6112	0.6108	0.8754	0.6412

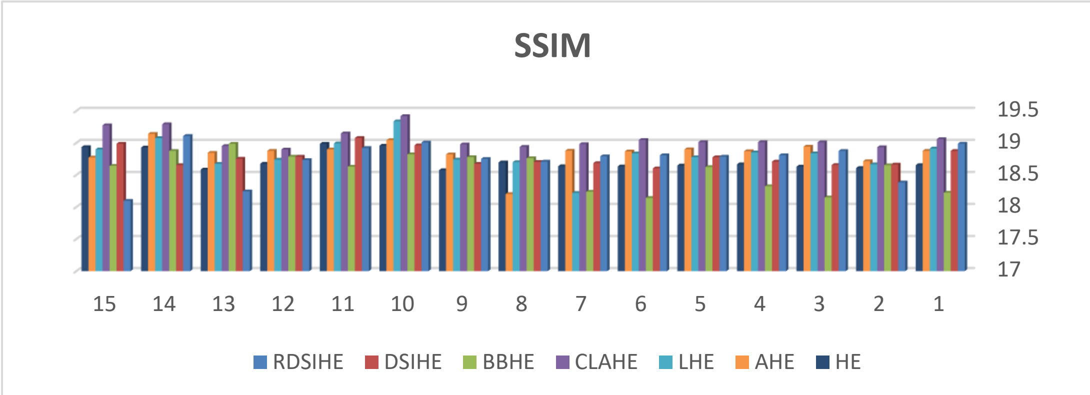

Fig. 3 -.SSIM values

Table 2 – Values of Entropy.

ImNo	HE	AHE	LHE	CLAHE	BBHE	DSIHE	RDSIHE
1	5.5068	5.4919	5.4103	5.6494	5.6517	5.9261	5.4199
2	5.4406	5.3448	5.2797	5.3474	5.2559	5.9678	5.2876
3	5.4011	5.7759	5.6422	5.5633	5.8331	5.9200	5.6534
4	5.7963	5.6078	5.5140	5.7332	5.7843	5.9157	5.3232
5	5.5016	5.7670	5.6695	5.1340	5.9063	5.9091	5.2311
6	5.8010	5.6259	5.5159	5.7390	5.7221	5.9188	5.0909
7	5.6581	5.4012	5.3086	5.5964	5.6302	5.9734	5.3765
8	5.5638	5.4600	5.8584	5.4467	5.1731	5.9834	5.6543
9	5.6400	5.4417	5.8772	5.4311	5.2462	5.9655	5.2876
10	5.1842	5.1590	4.9008	5.1378	5.2252	5.9314	4.5432
11	5.0494	5.1590	4.9649	5.0137	5.0159	5.9789	4.4321
12	5.7621	5.5112	5.8564	5.7654	5.6009	5.9876	5.5543
13	5.8342	5.6897	5.5239	5.8099	5.7765	5.9975	5.1232
14	5.6897	5.6874	5.3876	5.7213	5.6257	5.9298	5.0987
15	5.6090	5.6009	5.5987	5.5765	5.6887	5.9009	5.7667

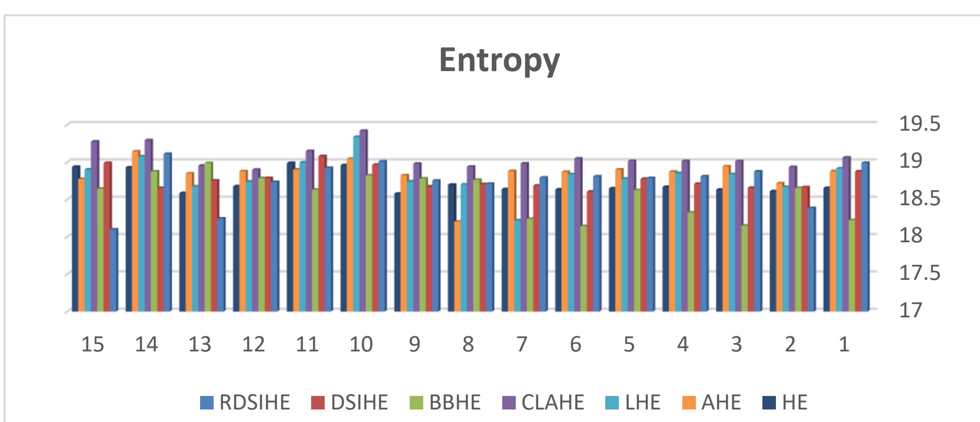

Fig. 4 -. Entropy values

Table 3 – Values of PSNR.

ImNo	HE	AHE	LHE	CLAHE	BBHE	DSIHE	RDSIHE
1	20.9675	20.9529	20.8551	21.1188	20.9420	21.0336	20.8567
2	20.9709	21.0301	20.9187	21.2393	21.0184	21.0179	20.9987
3	20.9884	21.0238	20.8731	21.1269	21.0226	20.9920	20.5644
4	21.0042	20.9658	20.8368	21.1385	20.8990	21.0332	20.8765
5	20.9998	21.0375	20.8349	21.2120	21.0097	21.0154	20.9875
6	20.9648	20.9608	20.8135	21.1642	20.9334	20.9270	20.7554
7	20.9392	20.9420	20.7949	21.2945	20.8765	20.9756	20.7200
8	21.0607	21.1367	20.9263	21.2634	21.0615	21.0560	20.9983
9	20.9381	21.0335	20.9802	21.2888	21.0173	21.0270	20.9099
10	20.8296	20.8420	20.7238	21.1637	20.7694	20.8483	20.7166
11	20.7674	20.8998	20.6669	21.2617	20.7592	20.8550	20.6854
12	21.2637	21.1227	20.8964	21.2354	21.0653	21.1432	20.8911
13	20.9441	21.1765	20.9765	21.2853	21.0232	21.0876	20.9113
14	20.9896	20.8698	20.7998	21.2413	20.7987	20.7654	20.0098
15	20.7398	20.8214	20.6435	21.0876	20.7908	20.8641	20.3432

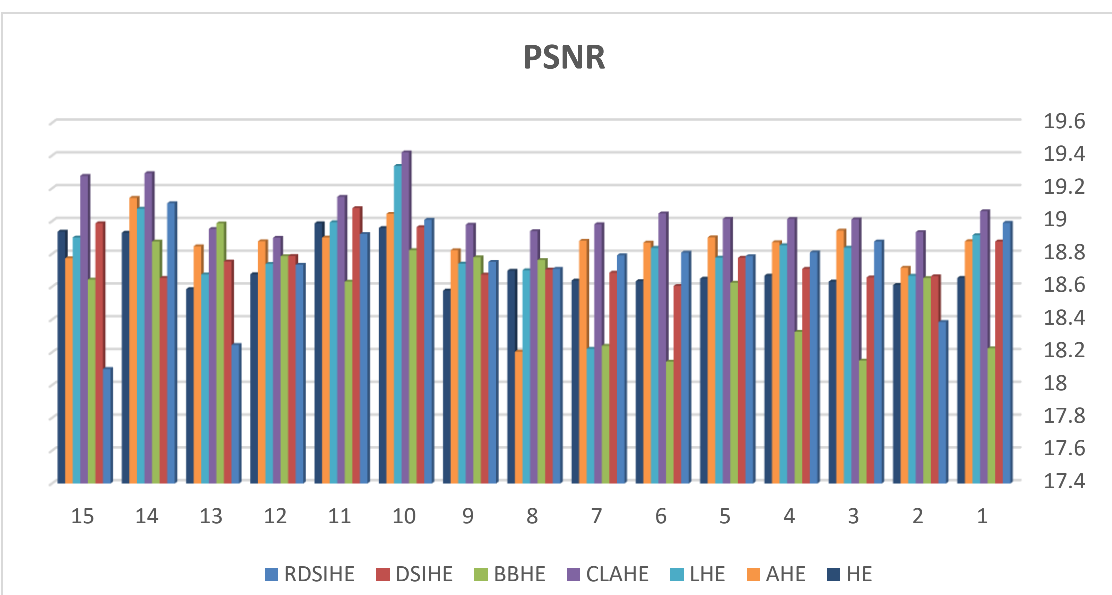

Fig. 5 -. PSNR values

Table 4 – Values of SNR.

ImNo	HE	AHE	LHE	CLAHE	BBHE	DSIHE	RDSIHE
1	18.6541	18.8784	18.9145	19.0607	18.2244	18.8765	18.9903
2	18.6108	18.7164	18.6671	18.9334	18.6534	18.6642	18.3854
3	18.6319	18.9427	18.8384	19.0121	18.1499	18.6568	18.8765
4	18.6682	18.8723	18.8537	19.014	18.3253	18.7099	18.81
5	18.6497	18.9017	18.7776	19.0147	18.6248	18.777	18.7866
6	18.6342	18.8695	18.8374	19.0478	18.1436	18.6051	18.8085
7	18.6382	18.8807	18.2218	18.9818	18.2401	18.6862	18.7921
8	18.698	18.2038	18.7009	18.9391	18.7629	18.7051	18.7098
9	18.5773	18.8229	18.7416	18.979	18.7801	18.6746	18.7521
10	18.9587	19.0449	19.3372	19.42	18.8234	18.9637	19.0091
11	18.9875	18.9009	18.9941	19.1489	18.6312	19.0797	18.9221
12	18.677	18.8778	18.7399	18.899	18.7864	18.7876	18.7344
13	18.5861	18.8468	18.6753	18.9523	18.9871	18.7543	18.2453
14	18.9295	19.1425	19.0764	19.2932	18.8765	18.6541	19.1098
15	18.9365	18.7739	18.9009	19.2765	18.644	18.9876	18.0983

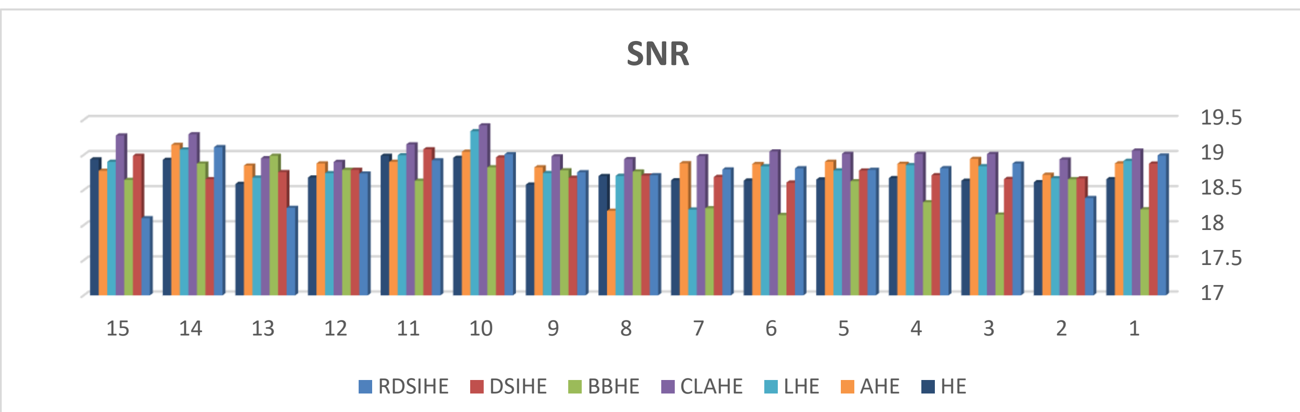

Fig. 6 -. SNR values

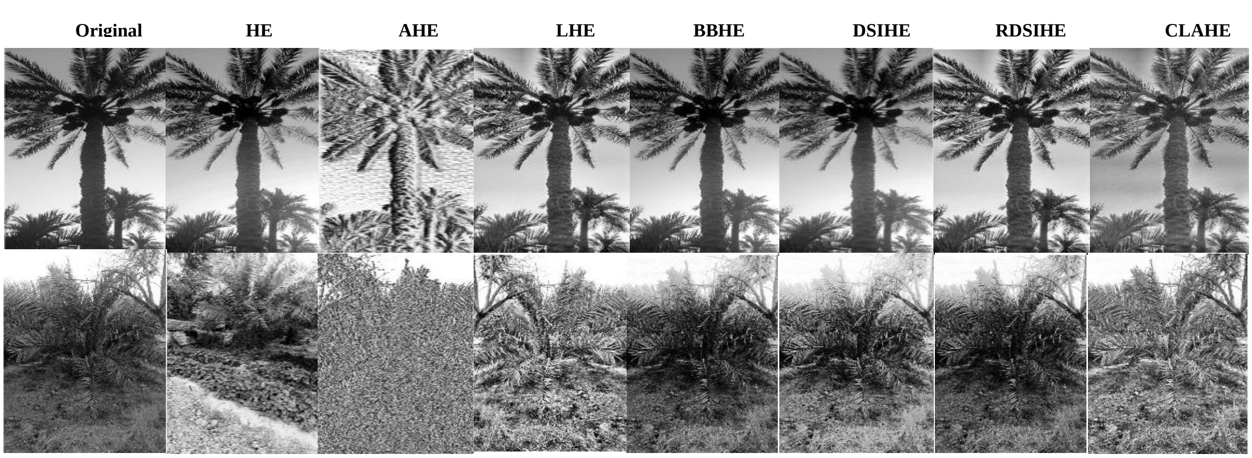

Fig. 7. samples of results

7. Conclusion

Image enhancement techniques give a large choice of styles which has used to adjust images for completing visually appropriate images. The determination of some techniques is actually a purpose of the certain task, image content, observer features and observing conditions. Hence, a comparative study of different enhancement techniques has well achieved for natural images. The main task for all techniques is to enhance the original images. Seven enhancement techniques have been applied of dataset which are HE, AHE, LHE, CLAHE, BBHE, DSIHE and RSIHE respectively. Therefore, the image must not miss its significant and important information but achieving image enhancement techniques.

The results have noted that DSIHE technique has produced a batter values of various measurements like PSNR, and entropy. It was observed that RSIHE which are the developed version of BBHE provides improved results according to measurements such as PSNR and SNR. So, these techniques can be used for the enhancement of natural images for good uses and applications.

8. References

[1] AbdulSaleem, S., & Abdul Razak, T. (2014). Survey on Color Image Enhancement Techniques using Spatial Filtering. *International Journal of Computer Applications*, *94*(9), 39–45. http://doi.org/10.5120/16374-5837

[2] Agrawal, P., Chourasia, V., Kapoor, R., & Agrawal, S. (2014). A Comprehensive Study of the Image Enhancement. *International Journal of Advance Foundation and Research in Computer*, *1*(7), 84–89.

[3] Bora, D. J. (2017). Importance of Image Enhancement Techniques in Color Image Segmentation: A Comprehensive and Comparative Study. Retrieved from http://arxiv.org/abs/1708.05081

[4] Butola, R., Pratik, S., & Kumar, U. (2015). A Comparison of Thresholding Based Image Enhancement Techniques. *International Journal of Computer Science and Mobile Computing*, *4*(1), 314–319. Retrieved from https://www.semanticscholar.org/paper/A-Comparison-of-Thresholding-Based-Image-Techniques-Butola-Pratik/f622866172bac74d1b91eed29d0009fb67c2449a

[5] Firman Ashari, I. (2021). The Evaluation of Image Messages in MP3 Audio Steganography Using Modified Low-Bit Encoding. *Telematika*, *14*(2), 133–145. http://doi.org/10.35671/telematika.v14i2.1031

[7] Firoz, R., Ali, M. S., Khan, M. N. U., Hossain, M. K., Islam, M. K., & Shahinuzzaman, M. (2016). Medical Image Enhancement Using Morphological Transformation. *Journal of Data Analysis and Information Processing*, *04*(01), 1–12. http://doi.org/10.4236/jdaip.2016.41001

[8] Iqbal, S., Hussain, L., Siddiqui, G. F., Ali, M. A., Butt, F. M., & Zaib, M. (2021). Image enhancement methods on extracted texture features to detect prostate cancer by employing machine learning techniques. *Waves in Random and Complex Media*, *2*(May 2022), 1–20. http://doi.org/10.1080/17455030.2021.1996658

[9] K.Nagaiah1, Dr. K. Manjunathachari2, D. T. V. R. (2015). Efficient Image Enhancement Techniques For Micro Calcification Detection In Mammography. *International Journal of Electrical and Electronics Engineers*, 1356–1363.

[10] Kaur, G., & Kaur, M. (2016). A Study of Transform Domain based Image Enhancement Techniques. *International Journal of Computer Applications*, *152*(9), 25–29. http://doi.org/10.5120/ijca2016911858

[11] Kaur, S. (2015). Review and Analysis of Various Image Enhancement Techniques. *International Journal of Computer Applications Technology and Research*, *4*(5), 414–418.

[12] Lee, J., Cho, S., & Kim, M. (2019). An End-to-End Joint Learning Scheme of Image Compression and Quality Enhancement with Improved Entropy Minimization, *1*, 1–25. Retrieved from http://arxiv.org/abs/1912.12817

[13] Li, J., Dong, Y., & Jiao, F. (2015). An efficient sparse code fusion method for image enhancement. *International Journal of Multimedia and Ubiquitous Engineering*, *10*(8), 55–64. http://doi.org/10.14257/ijmue.2015.10.8.06

[14] Liang, D., Li, L., Wei, M., Yang, S., Zhang, L., Yang, W., … Zhou, H. (2021). Semantically Contrastive Learning for Low-light Image Enhancement. In *SixthAAAIConferenceonArtificialIntelligence* (pp. 1555–1563). Retrieved from http://arxiv.org/abs/2112.06451

[15] Maithri, V., Dharshini, B. P., Vaishnavi, K., & Science, D. C. (2022). Night Time Vehicle Detection And Approximate Colour Detection Using Image Enhancement Techniques . *International Research Journal of Education and Technology*, *4*(5), 139–146.

[16] Nayak, D. R., & Ystem, I. I. I. P. R. S. (2016). Image Enhancement Using Fuzzy Morphological Transformations. *International Journal of Modern Computer Science*, *4*(6), 58–59.

[17] Patel, P., & Bhandari, A. (2019). A Review on Image Contrast Enhancement Techniques. *Smart Moves Journal Ijoscience*, *5*(7), 5. http://doi.org/10.24113/ijoscience.v5i7.217

[18] Qi, Y., Yang, Z., Sun, W., Lou, M., Lian, J., Zhao, W., … Ma, Y. (2022). A Comprehensive Overview of Image Enhancement Techniques. *Archives of Computational Methods in Engineering*, *29*(1), 583–607. http://doi.org/10.1007/s11831-021-09587-6

[19] Qureshi, M. A., Deriche, M., Beghdadi, A., & Mohandes, M. (2015). An information based framework for performance evaluation of image enhancement methods. *5th International Conference on Image Processing, Theory, Tools and Applications 2015, IPTA 2015*, *2*(3), 519–523. http://doi.org/10.1109/IPTA.2015.7367201

[20] Rani, A. (2014). Image Enhancement using Image Fusion Techniques. *International Journal of Advanced Research in Computer Science and Software Engineering*, *4*(9), 413–416.

[21] Rasheed, M., Ali, A. H., Alabdali, O., Shihab, S., Rashid, A., Rashid, T., & Abed Hamad, S. H. (2021). The Effectiveness of the Finite Differences Method on Physical and Medical Images Based on a Heat Diffusion Equation. *Journal of Physics: Conference Series*, *1999*(1). http://doi.org/10.1088/1742-6596/1999/1/012080

[22] Rasti, P., Taşmaz, H., Daneshmand, M., Kiefer, R., Ozcinar, C., & Anbarjafari, G. (2016). Satellite image enhancement: Systematic approach for denoising and resolution enhancement. *Dyna (Spain)*, *91*(3), 326–329. http://doi.org/10.6036/7676

[23] Roy, S., kumar Jain, A., Lal, S., & Kini, J. (2018). A study about color normalization methods for histopathology images. *Micron*, *114*(August), 42–61. http://doi.org/10.1016/j.micron.2018.07.005

[24] Sankpal, S. S., & Deshpande, S. S. (2016). A review on image enhancement and color correction techniques for underwater images. *Advances in Computational Sciences and Technolog*, *9*(1), 11–23.

[25] SatyasangramSahooa, & Dr. R. Lakshmi. (2021). Classification among Image Enhancement Techniques for Computed Tomography scan by using CancerNet neural network. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(3), 4938–4941. http://doi.org/10.17762/turcomat.v12i3.2006

[26] Shaikh, M. a, & Sayyad, S. B. (2014). Color Image Enhancement Filtering Techniques for Agricultural Domain Using Matlab. In *International Symposium on "Operational Remote Sensing Applications: Opportunities, Progress and Challenges* (pp. 1–5).

[27] Shaker, E., Baker, M., & Mahmood, Z. (2022). The Impact of Image Enhancement and Transfer Learning Techniques on Marine Habitat Mapping. *Gazi University Journal of Science*, *36*(2), 1–16. http://doi.org/10.35378/gujs.973082

[28] Sharma, S., Agrawal, S., & Munjal, M. (2022). Technical Assessment of Various Image Enhancement Techniques using Finger Vein for personal Authentication. *Journal of Information Technology Management*, *14*(2), 200–224. http://doi.org/10.22059/JITM.2022.86666

[29] Silva, D. F., Yeh, C. C. M., Zhu, Y., Batista, G. E. a. P. a., & Keogh, E. (2019). Fast Similarity Matrix Profile for Music Analysis and Exploration. *IEEE Transactions on Multimedia*, *21*(1), 29–38. http://doi.org/10.1109/TMM.2018.2849563

[30] Singh, G., & Mittal, A. (2014). Various Image Enhancement Techniques- A Critical Review. *International Journal of Innovation and Scientific Research*, *10*(2), 267–274.

[31] Wang, Y., Wan, R., Yang, W., Li, H., Chau, L.-P., & Kot, A. C. (2021). Low-Light Image Enhancement with Normalizing Flow. In *Conference on Artificial Intelligence* (pp. 1–9). Retrieved from http://arxiv.org/abs/2109.05923

[32] Yadav, S. K., Kumar, S., Kumar, B., & Gupta, R. (2017). Comparative analysis of fundus image enhancement in detection of diabetic retinopathy. In *IEEE Region 10 Humanitarian Technology Conference 2016, R10-HTC 2016 - Proceedings* (Vol. 7, pp. 1–5). http://doi.org/10.1109/R10-HTC.2016.7906814

[33] Yang, C., Jin, M., Jia, X., Xu, Y., & Chen, Y. (2022). AdaInt: Learning Adaptive Intervals for 3D Lookup Tables on Real-time Image Enhancement. *IEEE*, *5*, 17522–17531. Retrieved from http://arxiv.org/abs/2204.13983

[34] Zhang, L., Wang, X., Dong, X., Sun, L., Cai, W., & Ning, X. (2021). Finger Vein Image Enhancement Based on Guided Tri-Gaussian Filters. *ASP Transactions on Pattern Recognition and Intelligent Systems*, *1*(1), 17–23. http://doi.org/10.52810/tpris.2021.100012

[35] Zhang, Q., Li, M., & Deng, Y. (2018). Measure the structure similarity of nodes in complex networks based on relative entropy. *Physica A: Statistical Mechanics and Its Applications*, *491*(October), 749–763. http://doi.org/10.1016/j.physa.2017.09.042