Performance Analysis of adaptive enhancement algorithms using Quality Metric Parameters for autonomous navigation of an unmanned mobile platform in a low illumination environment

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Abstract.

An efficient technique for enhancing the contrast of a low light environment in an unmanned mobile platform is emphasized in this paper. The information lost in the image is to be avoided for that Histogram Equalization (HE) techniques is used to make the smoother curve in the histogram. In this paper, we have considered six algorithms ESHE, RMSHE, ClaRMSHE, R-ESIHE, RS-ESIHE and WTHE. In these algorithms the quality metrics like MSE, RMSE, RMSE_SW, SSIM, UQI, MS-SSIM, ERGAS, SCC, SAM, VIFP and PSNRB have been considered. The performance analysis with respect to the quality metrics for all the algorithms is examined and is observed that RS-ESIHE, ESHE & WTHE are having good performance in contrast image enhancement in that RS-ESIHE has better performance, which improves the contrast of the image. The novelty of this paper is that all the new alogorithms related to adaptive image enhancement techniques have been implemented and simulated using Matlab tool. The quality metrics of each image has been compared with all algorithms using sewar library and matlab tool box. Depending on the quality metric parameter, the RS-ESHIE has better outcome compared to other algorithm which would be implement for medical robot for hospital and robots for agriculture applications.

Keywords. ESIHE, RMSHE , claRMSHE, R-ESIHE , RS-ESIHE , WTHE, MSE, RMSE, RMSE_SW, SSIM, UQI, MS-SSIM, ERGAS, SCC, SAM, VIFP and PSNRB

1. INTRODUCTION

Digital image Enhancement technology are considered one of the basic problems in computer vision. Monitoring, visualization systems, human interactions, and computer interactions, and many applications are widely used in many applications. In most occasions, the contrast of digital image or video is very poor. This can be caused by many situations, including the inappropriateness of the equipment for the purchase of the worker and the inappropriateness of the equipment for purchasing images. In most cases, the captured scene is an adverse environmental condition, such as an adverse environmental condition like dark light, cloudy and so on. These conditions can also reduce the quality of the contrast. Considering the above problems, many researchers are still focused on improving the contrast of the image. In general, how to improve bad contrast images, it is widely used for two categories of direct improvement and indirect improvement. Direct Improvement Method allows you to determine the contrast of the image as a particular contrast period. However, many of these parameters cannot simultaneously measure the contrast of the image's simple and complex template. There are a variety of ways to improve the image to increase contrast of the digital image. For example, histogram equalization (HE) is a most extensively used because of its ease and easy to implement. Unfortunately, Histogram equalization do not give satisfactory results in all occasion.

Low light adaptive Image enhancement algorithms have been extensively used in many image processing applications in which the quality of a digital image from a video is important for human interpretation. Contrast is a best parameter for assessment of digital image quality. Contrast creates the difference in luminance reflected by 2 surfaces which are adjacent to it and can also be used to improve the visual properties objects from the image. In human eye perception, contrast is can be obtained by the bright and color differences of an object from another objects. Human eye visual system is sharp with respect to contrast than the brightness. Henceforth all humans can perceive the world in the same way in spite of abrupt changes in lighting conditions. Histogram equalization algorithms could be accomplished to solve the problems in image processing.

2. LITERATURE SURVEY

W. Wang et. Al. proposed a Image captured below terrible illumination situations frequently showcase traits like less brightness, less contrast, a low grey values, and colour distortion, in addition to substantial noise, which severely have an effect on the subjective visible pact on eyes of human and restrict the overall efficiency of diverse system imaginative and prescient. The position of low illuminated image is to enhance the visible impact of such digital images for the advantage of further process of the image. This paper proposes the principle strategies enhancement of images evolved in few decades. [1] .

K. K. Koonsanit et. Al. B. Instant digital Image, No video-Processing, Indoor-Storage, and Low Dose in radiations. Generally, X-ray images from digital flat detectors include poor image quality that might not be used for diagnostic planning and treatment plans. Thus, pretreatment techniques are mandate to improve the image quality. The work presents the image enhancement of digital mamogram imaging using so-called Nclahe technique based on regional improvement [2].

K SINGH et al. proposed contrast enhancement techniques with removal of noise in the dark images in DCT areas. The improved techniques is recycled to the transition DCT coefficient submitted from the inferior state in the improved state. This is caused by internal noise that is existing due to the deficiency of appropriate illuminated image and can be modelled by a common two-stability systems. This technique employs fewer adaptive processing to improve image contrast and colour information while ensuring better quality[3].

3. ADATIVE IMAGE ENHANCEMENT

HE is a method used for contrast enhancement in digital images that tend to alter the digital image taken from a video to increase the brightness. Maintaining the actual brightness is very much required. The main goal of HE is to equalize the histogram of the input images. To perform the HE technique is to measure the current sum of the histogram values, to divide the entire image by the maximum values of pixels to normalize the current total, to multiply the digital image with normalized value by the highest gray value and round to the nearby integer and finally to map grayscale values with a one-to-one mapping.

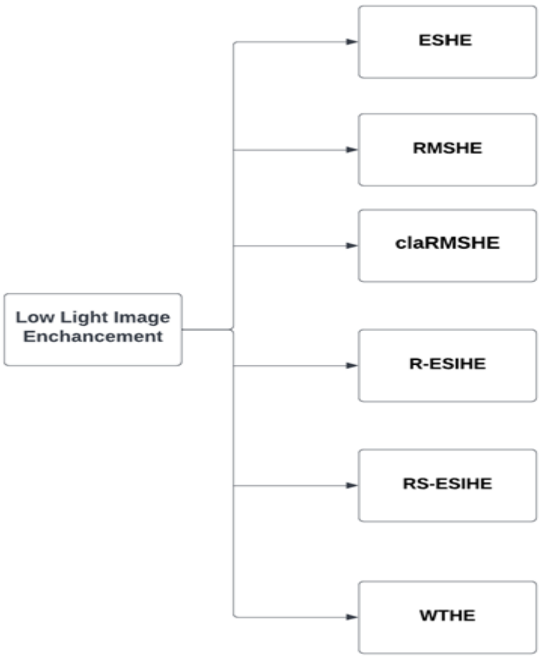

Fig 1: Low Light Adaptive Image enhancement algorithms

In this paper Low Light Image enhancement algorithms like ESHE, RMSHE, claRMSHE, R-ESIHE, RS-ESIHE, WTHE with quality metrics have been analysed.

ESHE is processing algorithm which is reputed in low illuminated image processing to improve the distinction of the image extracted from the image/video taken from a camera for the unmanned area.

RMSHE algorithm for low light adaptive image enhancement is recursively used to split the histogram on the internal value of mean. The average illumination of the digital image processed is about the same as the glowing of the input image which is averaged. The RESIHE method is another form of ESIHE. The quantity of recursion depends on the subtraction in exposure of consecutive iterations. The steps for the algorithm is to divide and balance the histogram of the image. The original given image is first classified into two images and is represented as given below.

$$P_L(k) = \frac{h_c(k)}{N_L} \quad for \;\; 0 \le k \le X_\alpha - 1 \qquad (1)$$

$$P_U(k) = \frac{h_c(k)}{N_U} \quad for\ X_\alpha \le k \le L-1 \qquad (2)$$

The claRMSHE is a widely used CLAHE and RMSHE algorithms combined together to extracts the objects in a dark environments. claRMSHE is also extensively used by the image processing researchers to increase the brightness and the contrast of a digital image.

Conceptually RSESIE, a another version of ESIE which does consecutive decomposition of the histogram. The RSESIE recursively decomposes it into recursive level r based on the value of threshold of HE, sub-histogram of 2r. To generate the sub-histograms which are decomposed are then individually made equal. To simplify the recursion level, r is assumed to be 2. RSESIE includes calculation of exposure thresholds, deletion of histograms, separation of histograms, and leveling of histograms. The Xa exposure threshold for the complete histogram is given below.

$$X_{al} = L\left[\frac{X_a}{L} - \frac{\sum_0^{X_a-1} h(k)k}{L\sum_0^{X_a-1} h(k)}\right] \qquad (3)$$

$$X_{au} = L\left[1 + \frac{X_a}{L} - \frac{\sum_{X_a}^{X_a-1} h(k)k}{L\sum_{X_a}^{X_a-1} h(k)}\right]^{\frac{1}{2}} \qquad (4)$$

WTHE is a new algorithm which can outperform complexity in image processing of the Histogram Equalization method and increase its durability.. The concept of WTHE is to alter the histogram before flattening. WTHE is performed by changing the image histogram by assigning weights and thresholds to each pixel prior to HE. The probability density functions of weighted & threshold is represented as P (kn) are given by:, as in:

$$P_{wt}(k_n) = \Omega\big(P(k_n)\big)$$

$$= \begin{cases} P_u & if\ P(k_a) > P_u \\ \left(\frac{P(k_n)-P_l}{P_u-P_l}\right) rXP_u & if\ P_l \le P(k_a) \le P_u \\ 0 & if\ P(k_a) < P \end{cases} \qquad (5)$$

The exceptional metrics likes MSE measures imply squared mistakes i.e., the imply squared distinction among the predicted and real values. RMSE is the rectangular root of the imply squared of all mistakes. RMSE_SW Calculates the imply squared blunders the usage of the sliding window. SSIM is used to degree the similarity among images. UQI offers a worldwide photo exceptional index. MS-SSIM is a greater superior shape of SSIM carried out throughout a couple of scales thru a multi-degree sub-sampling process. ERGAS which Calculates the general and dimensional relative blunders. It is used to calculate the exceptional of the mixed photo in phrases of the imply well-known blunders for every variety of processed images. SCC Calculates the spatial correlation coefficient. It is a numerical degree of a kind of correlation, this means that that there's a statistical dating among variables. The Spectral Angle Mapper (SAM) is an automatic technique for at once evaluating photo spectra to a regarded spectra. VIFP is a complete reference photo exceptional evaluation index primarily based totally on herbal scene facts and the perception of photo records extracted through the human visible system. The top sign-to-noise ratio with blocking off effect (PSNRB) quantifies the broken diploma of noise with appreciate to the enter photo. The better the PSNRB is, the higher the de-noised digital image sign is.

4. EXPERIMENT RESULTS

MATLAB 2021 is applied to the algorithm considered here. The Personal computer is configured with i5 processor, 16G RAM, and Windows NT 10 operating system. The experimental scenes include image 1 : evening just started but we are able to see around.

Fig2a : input image 1

Fig2b : ESHE output

Fig2c : RMSHE output

Fig2d : cla-RMSHE output

Fig2e : R-ESIHE output

Fig2f : RS-ESIHE output

Fig2g : WTHE output

Image - 2 Evening little darker but still able to see with difficulties

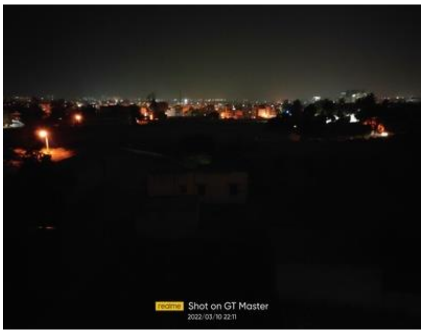

Fig 3a : Input image 2

Fig 3b.: ESHE output

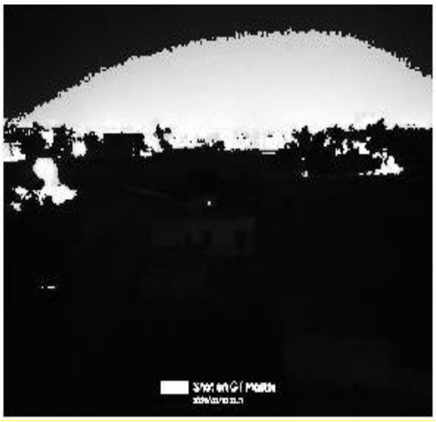

Fig 3c.: RMSHE output

Fig 3d.: cla RMSHE output

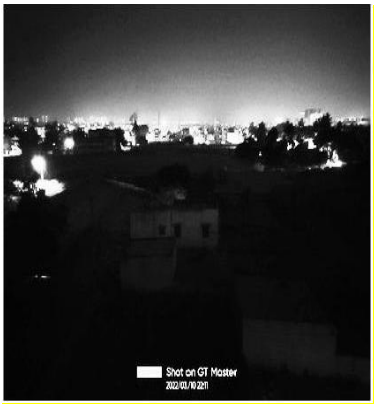

Fig 3e.: R-ESIHE output

Fig 3f.: RS-ESIHE output

Fig 3g: WTHE output

Image – 3 Evening Dark.

Fig 4a: Input image 3

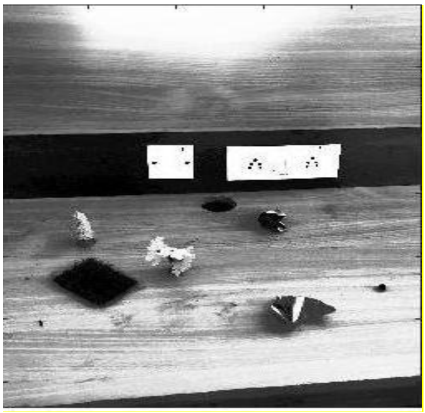

Fig 4b: ESHE output

Fig 4c: RMSHE output

Fig 4d: claRMSHE output

Fig 4e: RESIHE output

Fig 4f: RS-ESIHE output

Fig 4f: RS-ESIHE output

With histogram equalization, the pixels are evenly spread. The resulting image with histogram equalization usually has an unnatural appearance, which means that the image is overemphasized. WTHE decreases the impact caused by histogram equalization. The adaptive image enhancement algorithms have been utilized to increase the contrast of the digital image is emphasized, the noise induced in the image as an upshot becomes higher and the image looks unnatural. Histogram Equalization and Weighted Thresholds Table I shows the calculated quantitative measurements MSE, RMSE, RMSE_SW, SSIM, UQI, MS-SSIM, ERGAS, SCC and SAM values for histogram equalization.

Table 1: Output for image 1 with quality metrics for ESIHE, RMSHE, claRMSHE

QM Parameters For Image 1	ESHE	RMSHE	claRMSHE
MSE	5084.200915	5277.096174	25563.15847
RMSE	71.30358	72.64366	83.42581
RMSE_SW	29.4817698	30.02523130	129.9505448
SSIM	0.242316, 0.600003	0.071950, 0.469785	0.598769, 0.724133
UQI	0.499230	0.499005	0.119048
MS-SSIM	0.56344643	0.217519	0.710930494
ERGAS	7572424.91	993358.6523	2053307.166
SCC	0.001312	0.005862	0.005707
SAM	1.129667	1.034359	1.127006
VIFP	0.030480	0.079122	0.079754
PSNRB	11.06753	10.90481	3.938166

Table 2 : Output for image 1 with quality metrics for R-ESIHE, RS-ESIHE, WTHE

QM Parameters For Image 1	R-ESIHE	RS-ESIHE	WTHE
MSE	5123.771684	9950.576715	7797.087177
RMSE	71.58052587	99.75257748	88.30111651
RMSE_SW	36.33088817	75.16261236	60.68850326
SSIM	0.53116, 0.716580	0.224892, 0.521556	0.598465, 0.726552

UQI	0.426449	0.314852	0.176146
MS-SSIM	0.658928	0.711639	0.452565
ERGAS	1012727.07	933778.231	2053307.166
SCC	0.004501	0.020476	0.009584
SAM	0.827387	0.926068	0.875468
VIFP	0.102563	0.141634	0.094495
PSNRB	10.87312	8.027420	9.053937

Table 3: result for image 2 with quality metrics for ESHE, RMESIHE, claRMSHE

QM Parameters For Image 2	ESHE	RMSHE	claRMSHE
MSE	18858.797058	12766.38973	6830.490986
RMSE	137.32733	112.9884495	82.646784487
RMSE_SW	123.2583009	64.50501232	35.49447975
SSIM	0.150495, 0.608782	0.583160, 0.673278	0.422295, 0.456406
UQI	0.0740318	0.1589600	0.084507
MS-SSIM	0.549302317	0.46418952	0.46071747144
ERGAS	158561.1621	409664.4216	100420.474247
SCC	0.062447	0.006754	0.009059
SAM	0.666790	0.875080	0.805904
VIFP	0.555932	0.129004	0.153298
PSNRB	5.218099	6.923819	9.782965

Table 4 :result for image 2 with quality metrics for R-ESIHE, RS-ESIHE, WTHE

QM Parameters For Image 2	R-ESIHE	RS-ESIHE	WTHE
MSE	16855.06	5894.5025	7698.6921
RMSE	129.8270	76.775666	87.742191

RMSE_SW	113.0840041	67.30782095	45.58062906
SSIM	0.217292, 0.667591	0.653790, 0.707731	0.5836152, 0.6845124
UQI	0.6143681	0.729776	0.627362
MS-SSIM	0.31187678187	0.501600148852	0.4649440077
ERGAS	421973.40116	121515.590870	275962.4941
SCC	0.0170458	-0.005022	-0.0777906
SAM	0.795673	0.9099325	1.110519
VIFP	0.2793599	0.232960	0.281539
PSNRB	9.1168440	5.742390	10.6591124

Table 5 : output for image 3 with quality metrics for ESHE, RMESIHE, claRMSHE

QM Parameters For Image 3	ESHE	RMSHE	claRMSHE
MSE	3789.981606	3833.6970185	7698.692119
RMSE	61.56282	61.91685	87.742191
RMSE_SW	28.6202533	28.78455	45.58062906
SSIM	0.5836152, 0.6845124	0.279591, 0.762191	0.565273, 0.718116
UQI	0.6143681	0.618640	0.426449
MS-SSIM	0.501600148	0.071623794	0.658928
ERGAS	1012727.073	155787.01130	155717.90543
SCC	0.0170458	-0.002775	-0.002754
SAM	0.827387	0.889752	0.897358
VIFP	0.2793599	0.048734	0.048861
PSNRB	9.1168440	11.53138	10.87312

Table 6 : Output for image 3 with quality metrics for R-ESIHE, RS-ESIHE, WTHE

QM Parameters For Image 3	R-ESIHE	RS-ESIHE	WTHE
MSE	10525.559	5123.7716	11815.41348
RMSE	102.59414	71.58052587	108.69872
RMSE_SW	85.246131	36.33088817	99.48488928
SSIM	0.177543, 0.455830	0.53116, 0.716580	0.566643, 0.720472
UQI	0.212141	0.618894	0.1742202
MS-SSIM	0.3460720	0.709533774	0.640070877
ERGAS	445686.87	121515.590870	280265.4211
SCC	-0.000177	0.020476	-0.0014917
SAM	0.753232	0.9099325	0.677614
VIFP	0.058564	0.141634	0.0766659
PSNRB	7.045328	11.60782	6.526448

Table 7: Performance evaluation of image enhancement algorithms

QM	Image 1	Image 2	Image 3
MSE	ESHE	RS-ESIHE	ESHE
RMSE	ESHE	RS-ESIHE	ESHE
RMSE_SW	ESHE	RS-ESIHE	ESHE
SSIM	WTHE	RS-ESIHE	WTHE
UQI	ESHE	RS-ESIHE	RS-ESIHE
MS-SSIM	RS-ESIHE	ESHE	RS-ESIHE
ERGAS	RS-ESIHE	RS-ESIHE	RS-ESIHE
SCC	RS-ESIHE	ESHE	RS-ESIHE
SAM	ESHE	WTHE	RS-ESIHE
VIFP	RS-ESIHE	ESHE	ESHE
PSNRB	ESHE	WTHE	RS-ESIHE

Performance evaluation based on the digital Images taken in dim conditions, including evening dark environment to test the reliability of the low exposure imaging method. Analysis of the visual results of fig. 8–14 shows that RS-ESIHE, ESHE & WTHE algorithms are best suited for especially in low light conditions.

5. CONCLUSION

This paper presents an effective way to increase the contrast of digital images. The histogram of the input image has been modified with a new feature to avoid information loss during image processing. The new algorithm is designed to make dark areas of the image high and bright areas low. A non-linear normalization transformation is to obtain a wider dynamic range of the low illuminated of the output image. After applying the proposed method, the sharpness of the image with non-uniform lighting was clearly improved. As a result of the experiment, it can be seen that the RS-ESIHE has superior image enhancement performance to other latest methods. This RS-ESIHE method is suitable for Adaptive image enhancement to visualize the low light and dark images which is suitable for unmanned platform and can be implement in mobile robot and drone applications. Analysis of the results shows that for these kind of images, RS-ESIHE is selected as the best Adaptive Enhancement method to be used. However, ESHE and WTHE is quite nearby to the RS-ESIHE. These methods are better suited to extract the information content of an image because it gives better results in terms of average information content.

6. REFERENCES

[1] W. Wang, X. Wu, X. Yuan and Z. Gao, "An Experiment-Based Review of Low-Light Image Enhancement Methods," in IEEE Access, vol. 8, pp. 87884-87917, 2020.

[2] K. Koonsani, S. Thongvigitmanee, N. Pongnapang and P. Thajchayapong, "Image enhancement on digital x-ray images using N-CLAHE," 10th Biomedical Engineering International Conference (BMEiCON), pp. 1-4, 2017.

[3] Soong-Der Chen and A. R. Ramli, "Contrast enhancement using recursive mean-separate histogram equalization for scalable brightness preservation," in IEEE Transactions on Consumer Electronics, vol. 49, no. 4, pp. 1301-1309, Nov. 2003.

[4] R.Sharmila, R Uma. "A New Approach To Image Contrast Enhancement using Weighted Threshold Histogram Equalization with Improved Switching Median Filter", International journal of advanced engineering sciences and technologies, vol. 7, No. 2, pp. 206 – 211.

[5] T.Saikumar , R.Chiranjeevi , M.Sai Phaneendra , E.Pranay , G.Bala Kiran, "Improved Recursive HE Algorithms for Low Exposure Images", International Journal of Engineering Technology Science and Research IJETSR, Vol. 5, No, 2018.

[6] K. Singh, R. Kapoor, "Image enhancement using exposure based sub image histogram equalization", Pattern Recogn. Lett. 36, pp. 10–14, 2014.

[7] S. Kumar, S. Choudhary, R. Gupta and B. Kumar, "Performance Evaluation of Joint Filtering and Histogram Equalization Techniques for Retinal Fundus Image Enhancement," 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), pp. 1-5, 2018.

[8] H Girish, T. G. Manjunat and A. C. Vikramathithan, "Detection and Alerting Animals in Forest using Artificial Intelligence and IoT," IEEE Fourth International Conference on Advances in Electronics, Computers and Communications (ICAECC), pp. 1-5, 2022.

[9] Ahmed, S. T., Sreedhar Kumar, S., Anusha, B., Bhumika, P., Gunashree, M., & Ishwarya, B. (2018, November). A Generalized Study on Data Mining and Clustering Algorithms. In *International Conference On Computational Vision and Bio Inspired Computing* (pp. 1121-1129). Springer, Cham.

[10] H. Aditya, T. Gayatri, T. Santosh, S. Ankalaki and J. Majumdar, "Performance analysis of video segmentation," 4th International Conference on Advanced Computing and Communication Systems (ICACCS), pp. 1-6, 2017.

[11] [10] Supriya, S. & Subaji, M, "Intelligent Based Image Enhancement using Direct and In-Direct Contrast Enhancement Techniques – A Comparative Survey", International Journal of Signal Processing, Image Processing and Pattern Recognition, Vol. 10, pp.167-184, 2017.

[12] Basha, S. M., Ahmed, S. T., & Al-Shammari, N. K. (2022). A Study on Evaluating the Performance of Robot Motion Using Gradient Generalized Artificial Potential Fields with Obstacles. In *Computational Intelligence in Data Mining* (pp. 113-125). Springer, Singapore

[11] S. Kumar, S. Choudhary, R. Gupta and B. Kumar, "Performance Evaluation of Joint Filtering and Histogram Equalization Techniques for Retinal Fundus Image Enhancement," 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), pp. 1-5,2018