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Image Enhancement based on the Histogram Equalization and Multiresolution Discrete Stationary Wavelet Transform

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ABSTRACT

In recent years, due to the tremendous development that took place on the Internet and its applications in the aspects of human life, the demands of using digital images have also increased dramatically, and that opens up horizons for scientific research in the area of enhancing the quality of the digital images by removing the noise that caused by to processes that are applied within network transmissions like performing storage, retrieval, and encryption to preserve privacy. All these effects are yielded to reduce image quality and loss of visual information. To surmount this problem, image enhancement methods are used to eliminate the noise while preserving supreme exact details and essential characteristics as much as possible in the digital image. The wavelet image enhancement technique played a critical role in this field by attempts to decrease noise in the image while keeping the vital features for image because of the capability to separate the image into sub-bands (sub-images) and influence the frequencies of each sub-band separately, where acquiring the original image content is essential to obtaining reliable performance.

Different enhancement techniques have been realized by many researchers so far. Each technique has its own privileges and shortcomings. In this work, a proposed procedure is presented and effectuated to the image modified by Additive White Gaussian Noise (AWGN). The proposed enhancement operation was achieved using the combination of Histogram Equalization with a two-dimensional stationary discrete wavelet transform (2D-SWT) as a multi-resolution analysis technique in image processing at three levels of decomposition to obtain revised results of the method of noise removing. To distinguish and eliminate noise from affected pixel points in the wavelet domain the 2D-SWT is used established on the hard and soft threshold systems on both high and low frequencies to decrease noise from the noisy image. Then, the multi-level 2D inverse wavelet transform (2D-IWT) is applied to eliminate noise and complete the synthesis of the image by the proposed image enhancement techniques.

In the end, the performance of the suggested methods has been evaluated by utilizing the Peak Signal to Noise Ratio (PSNR). Practical measurements determine that the results of the suggested techniques enhanced the PSNR by about (16.16%) with respect to the outcomes of the previous works, and the structure of the image quality has also been improved in terms of edges retaining and greater noise elimination.

KEY WORDS: Digital Image Denoising, Multi-resolution Stationary Wavelet Transforms, Histogram equalization, AWGN noise, Thresholding techniques.

1. INTRODUCTION

The considerable distinctive style for humans to obtain details is to visually scan images that include a lot of details that can support people create determinations, the better quality the information they get, then the more useful proper steps they can produce via information. For assemble additional benefits, the image needs to improve the proper details of the image. Image improvement is a significantly meaningful image procedure in digital image processing, in order to display the components of noisy images [Ye, 2021]. So, image quality plays a critical role to determine the capacity to get thorough details from obtained images in many areas that deal with digital images [Mustafa, 2021].

One of the causes for reducing the image quality is what can be called noise, which is any undesirable mixed image information and noise usually can be little significance with high frequencies or a misshaping that appears in the digital image and may harm the details of the image. Noise occurs in images from numerous causes by implementing or strategy, communications reception. The image is frequently polluted by some noise resident in the creation approach and equipment or injected into the image pending its communication. There are various kinds of noise arising in images, such as impulse noise, uniform noise, Salt-and-Pepper, and additive Gaussian noise [Sami, 2016; Ramadhan,2017; Ferzo, 2020].

Additive White Gaussian Noise (AWGN) is a kind of noise produced by low-quality image accession, a noisy domain, or inner noise in communication media. It is necessary to improve the image quality by removing noise from the noisy image as far as allowable while maintaining the basics of important information properly in the image so that the image becomes as close as possible with the qualities and information it contains to the original image [Ferzo, 2020].

The image enhancement by reducing the noise is an important preprocessing stage for the investigation of images. Experimenters persist to concentrate on it to get a more suitable rate of observable assurance [Saluja,2015; Ferzo, 2020]. The corrupted images with (AWGN) noise can be denoised using wavelet technique is approvingly efficient by its capacity to separate and distribute the frequencies contained in the image into a separate group of bands, and it is possible to process each band individually, and then the image can be reconstructed by these denoised bands. In its basic form, each point is thresholded by the comparison against a value, named a threshold operation. There are numerous threshold methods analyzed and utilized by experimenters to calculate the threshold value [Wang,2017; Ferzo, 2020].

In this work, there are two threshold methods assigned to calculate threshold value that is the hard threshold method and the SURE shrink threshold method. The noise utilized in this study is the Additive White Gaussian Noise (AWGN), for the opportunity of this kind of noise occurring in images is additional effective than other kinds, and noisy image with AWGN is better difficult for the image improvement procedure [Sami, 2016; Mustafa, 2021].

Below formula 1 can be used to show the additive noise components [Saxena,2014; Mustafa,2021]:

$$Gm(i,j) = G(i,j) + m(i,j)$$
(1)

In formula 1, G(i,j) is the original image without noise, m(i,j) is the noise, Gm(i,j) is the noisy form of the image, and (i,j) is the position of the pixel inside the image.

At the beginning of the image improvement method, the noise will be estimated in the noisy images by using the noise estimator called the Robust Median Estimator Equation [Sami, 2016, Ferzo, 2020].

The goal of this work is to prepare and execute an approach for digital images enhancement. The suggested approach seeks to analyze the use of the combination of Histogram Equalization with a two-dimensional stationary discrete wavelet transform (2D-SWT) as a multi-resolution analysis technique in image processing at three levels of decomposition to acquire improved results for the noise reduction method. To determine and reduce noise from noisy pixel points in the wavelet domain the 2D-SWT is utilized established on the hard and soft threshold techniques on both high and low frequencies to reduce noise from the noisy image. complete the synthesis of the image by the proposed image enhancement techniques. The performance of the suggested methods will be evaluated by using the Peak Signal to Noise Ratio (PSNR).

1.1 Literature Review

The area of digital image enhancement, especially for preserving the essential information and details to improve the visual quality from corrupted images stays to be a rich zone for more study work. The following are some scientific references whose authors dealt with methods of applying different algorithms and methods in order to achieve an improvement in the quality of digital images

Sami I et al. in 2016 [Sami, 2016] presented a procedure established by involving Wavelet transform with a two-layer analysis on the experimented images that are polluted by several ratios of the additive Gaussian noise. because of the characteristic of the Wavelet transform to disintegrate the image into sub-bunds, and by employing various kinds of wavelets transform filters, the testing outcomes indicate that the suggested procedure gives the improvement in the range of both MSE and PSNR.

Shukla and Verma, [Shukla, 2016] suggested a Hybrid Bilateral filtering approach to enhance the denoising method of digital images and (Salt and Pepper) noise was insinuated into the image. The median filter and bilateral filter were both utilized to enhance the goodness of the image obtained by the denoising method. This method provides a more satisfactory outcome than the extant methods that utilize Median filter, Wiener Filter, and Bilateral filter all alone. The outcomes illustrate that the suggested strategy has improved the implementation for reducing noise. The performance of the denoising method is evaluated by (PSNR).

Wang, J., et al. in 2017 [Wang,2017], suggested a new procedure established by employing the Wiener filter with a high-resolution assessment which estimates the image data while keeping the edge attributes. The outcomes are studied using the PSNR. Observed outcomes show that the suggested method ultimately enhances accurate and subjective outcomes; accordingly, the suggested strategy triggered the removal of image noise but with edge attributes conserving.

Ramadhan et al. in 2017 [Ramadhan, 2017] investigated utilizing several filters for Wavelet transforms to analyze images in proper sub bands. They studied varieties that constructed an adequate effect for digital image noise reduction systems. Two strategies put for image enhancement have been employed established by utilizing median filter mixed with DWT: the two traditional denoising strategies pivoting on involving the DWT only or the median filter only and combining between the two procedures. Through the study of these subbands, the image improvement strategies apply to four issues with the use of the PSNR criteria for testing the execution of the suggested techniques.

Tayade P. M., and S.P. Bhosale in 2018 [Tayade, 2018] suggested a modified procedure established by using the Dual-Tree Complex Wavelet Transform and interpolation. The suggested procedure concentrated on the improvement of the precision of the medical images that have low precision. Different quality verification standards like PSNR and MSE have been employed to calculate the performance of the method of improving precision and defining the goodness of enhanced photos. The practical outcome indicates that the suggested procedure has a softer and better precise ratio than the DWT image.

Yuanmin Xie et al 2019 [Xie, 2019], examined the concept of histogram equalization for image processing., and implemented image improvement experimentations by MATLAB. The outcomes indicate that the histogram equalization procedure has a useful effect. It will improve the contraindication of the image and emphasize the characteristics of the image.

Ferzo et al 2020 [Ferzo, 2020], presented a suggested strategy to enhance the image that has been influenced by Additive White Gaussian Noise (AWGN). The presented approach was realized employing a Wiener filter before and after the wavelet transform. Threshold strategies and Wiener filter have been utilized for the enhancement. Also, in their study, the image is enhanced by employing the concept of utilizing Wiener filtering and enhancement technique in the wavelet domain with multiresolution at three analysis layers. The observed estimation demonstrates that the outcomes of the suggested strategies provide advancement of about 17.5% via the comparison with the achievements of the previous studies and the significance of images is enhanced in terms of noise diminution sounder than utilizing a wavelet transform or Wiener filter solo as well as edges conservation.

Mustafa F. M. et al, 2021, [Mustafa, 2021], presented a new strategy for image noise decrease as an enhancement method that utilizes threshold and histogram equalization executed in the wavelet domain. Various kinds of wavelet filters were experimented with to get the improvement in outcomes for the procedure of image denoising. Besides, the impact of removing one or more of the high-frequency bands in the wavelet domain has experimented too. The MSE and PSNR criteria are employed for evaluating the modification in the image enhancement method. A rapprochement completed with two previous research indicates the worth of the techniques suggested and executed in this work. The suggested techniques of involving the median filter before and after the histogram equalization techniques show a modification in implementation and worthiness corresponding to the issue of employing discrete wavelet transform only, consistent with the cases of multiresolution discrete wavelet transform and the step for removing bands.

Jeevan F. M. et al, 2021, [Jeevan, 2021], image improvement method that can be considered as a mixture of spatial domain and wavelet domain has been suggested and examined. The improvement is executed in two various areas. The first area is by employing the Gabor filtering and median filtering are fulfilled in the wavelet domain. After that, the processed image is transformed to the time domain and the adaptive histogram equalization is executed in the second area. Both quantitative estimation and visual assessment indicate that the suggested image improving technique provides more satisfactory outcomes.

2. DIGITAL IMAGE ENHANCEMENT

Image enhancement is a fundamental technology and present an essential role in digital image processing. Image enhancement can rise the effectiveness of the image, and improve the overall brightness and clarity of the image [Javeen, 2021]. In this work, image enhancement will focus on removing noise as much as possible from a noisy image because, in the current world, image-based visual communication is generally used using digital images. This work will utilize three grayscale images with dimensions (256x256) and a multiresolution two dimensions stationary wavelet transformation (2D-SWT) will be applied in order to obtain wavelet bands and up to three levels of wavelet analysis. The noise in digital images is due to addition, reduction, communication and interface, and the use of defective devices [Mittal, 2019]. The type of noise utilized in this study is the Additive White Gaussian Noise (AWGN) with two ratios (Noise Sigma = 15 and =25).

The enhancement process will depend on involving the threshold techniques and testing the performance of wavelet filters to obtain the best performance and to obtain which filters are most suitable for this application. Besides, the Histogram Equalization method will be used for many cases in the image enhancement suggested methods individually and also as a hybrid with threshold techniques in the wavelet domain. In this study, the Mean Square Error (MSE), and the Peak Signal to Noise Ratio (PSNR) are both used to evaluate the performance of the proposed methods of the image enhancement. The following equation will show the formula to obtain the MSE and the PSNR values [Sami, 2016; Frezo, 2020, Mustafa, 2021]:

$$MSE = \frac{1}{rows.col} \sum_{r_{1}=0}^{rows-1} \sum_{r_{2}=0}^{col-1} [F(r_{1}, r_{2}) - I(r_{1}, r_{2})]^{2}$$
(2)

$$PSNR = 10 .\log \frac{(255)^2}{MSE}$$
(3)

Where:

I (*r1*, *r2*): Original image. F (*r1*, *r2*): New image. *rows* and *col*: the image size. 255: Max pixel value of the grayscale image.

2.1 Wavelet Transform Domain

By using the wavelet transform, the essential information of time can be preserved by overcoming the main drawback that appears due to the use of the Fourier transform. This drawback appears because the Fourier transform is localized just in the frequency domain, while the wavelet transforms reasonably localized in the time and frequency domains, and the time details that are beneficial in numerous contexts can't be lavish. Wavelet gives outstanding performance in removing noise from the digital images due to the features such as sparsity and multiresolution configuration [Saluja,2015; Ye, 2021].

Wavelet recreates the work of the lens via a function that is tested. Extending and interpretation are the two essential features of the wavelet transform that indicate a set of model functions. Wavelet transform is a robust tool used for noise elimination and has the feature of the ability to disentangle the precise segments in the image. It can be considered as a high-speed computational operation and cost low response time [Saluja,2015].

One of the most powerful denoising techniques is the Wavelet Transform. This approach separates the noisy image into subband images, including three highfrequency subbands and a low-frequency subband, HH, HL, LH, and LL. The high-frequency sub-band represents edge, shape, and particular details, while the lowfrequency sub-band indicates background details. The high-frequency sub-band is correlated and manipulated with the threshold without affecting the points of the lowfrequency wavelet band. The threshold approach and inverse wavelet transformation are then used to obtain the enhanced image [Ferzo, 2020; Ye, 2021].

2.2 The Thresholding Techniques

Because the wavelet transform is a useful implement for frequencies separating, which is useful for reducing noise in digital images, the thresholding process is applied in the wavelet domain. A good threshold value can be utilized to achieve meaningful gains [Mustafa,2021]. The thresholding method is an uncomplicated non-linear process utilized to reduce the noise inside the wavelet's bands. In this process, the threshold value that can be implemented in three primary stages is compared to each point inside the specific band of the wavelet coefficients. The first stage is to compute the points or can be called the coefficients of the specific wavelet band, that is a linear process. While the second stage contents these points being thresholded. In the latest stage, the thresholded bands are used to reconstruct the enhanced image by involving the inverse wavelet transform [Ferzo, 2020]. Depending on the type of threshold method that has been used, the procedure will be used and applied on each thresholded point in the specific band.

Accordingly, the threshold is valuable while utilized to decrease the noise for the digital images when involved in Wavelet Domain. In this study, the hard and the soft threshold technologies will be used.

2.2.1 Hard Threshold

In the hard threshold kind, each point in the wavelet band (points as pixels) is analogized to a threshold weight. If the wavelet coefficient is less than the threshold weight, then the point will be replaced by the zero value, while the value which is greater than the threshold weight, it kept without changes. The mathematical formula below illustrates the hard threshold [Sami, 2016; Ferzo, 2020, Mustafa, 2021]:

$$Pe(i,j) = \begin{cases} W(r1,r2) & When W(r1,r2) \ge Thx\\ 0 & When W(r1,r2) < Thx \end{cases}$$
(4)

Where:

W(r1,r2): is the noisy wavelet coefficient.

Pe(r1,r2) :is then denoised wavelet coefficient.

r1: is decomposition level.

r2: is the location of the detail component.

Thx: is the representative of the threshold value for the sub-band x.

$$Thx = \frac{\sigma^2}{\sigma_x} \tag{5}$$

Where: σ^2 is the noise value inside the noisy image, that is calculated by utilizing the Robust Median Estimator formula, and σx is the standard deviation of the given sub-band x [Tai-sheng, 2015, Mustafa, 2021]. The Robust Median Estimator Equation is as below:

$$\sigma = Median(|x(i,j)|)/0.6745$$
(6)

Where:

x(i, j) describe the computation of diagonal sub-band for the first level of the wavelet transformation analysis (HH or HL).

2.2.2 Soft Threshold

Soft threshold shrinks the values of the wavelet towards zero; for this reason, it is sometimes known as the wavelet shrinkage process. Soft thresholding produces an image that is visually agreeable than hard thresholding [Saha, 2015]. The wavelet coefficients in the wavelet domain are softer after soft thresholding, and the reconstructed image also shows more inferior when determined with the hard thresholding technique. Soft thresholding is represented in the equation below [Koranga, 2018].

$$\widehat{W}_{j\,i} = \begin{cases} W_{ji} + T, & if \ |W_{ji}| \ge T \\ W_{ji} - T, & if \ |W_{ji}| \ge T \\ 0, & if \ |W_{ji}| < T \end{cases}$$
(7)

Where:

W j i: are noisy wavelet coefficients.

Ŵ j i: are denoised wavelet coefficients.

j: is decomposition level.

i: is the location of the detail component.

T: is the represent of threshold value.

The soft threshold technique allows shrinkage treatment to reduce the wavelet coefficients whose calculations are higher approximated to the threshold (soft threshold is a development of the hard thresholding), originally if the values are lower in comparison to a threshold value, they are assigned to a zero, and then the non-zero points are shrink to 0. If *Wj* i \geq T, the soft threshold wave is (*Wji* + T) [Koranga, 2018]. Because the soft threshold is a continuous function, the drawbacks in the hard threshold method can be well treated. Thus, the determinations endured are comparatively pure with the wavelet coefficients having big absolute values. However, if decreased, it will result in some high-frequency data losses. There are numerous denoising methods for calculating the threshold function in image enhancement systems [Al-Azzawi, 2012].

In this work, the method SureShrink will be used as a soft threshold technique, it can be considered as an adaptive thresholding technique where the level-by-level procedure of the wavelet coefficients is completed. At each level, a threshold that reduces the neutral Stein's hazard evaluation is used in the matter that there is info that the wavelet expression of that layer is not scatters [Frezo, 2020]. SureShrink is used in the wavelet domain to repress additive noise where a T SURE threshold is used to denoise. The threshold parameter T SURE is represented as indicated by the formula as follows [Rai et al. 2012]:

$$T_h = \sigma_n \sqrt{2\log L} \tag{8}$$

(SURE (Th; Y)) is represent by:

$$SURE(T_h; Y) = \sigma^2 - \frac{1}{L} \cdot [2\sigma_n^2 \{i: |Y_i| \le T_h - \sum_{i=1}^L min(|Y_i| \cdot T_h)^2 \}]$$
(9)

Where:

 σ^2_n : the variance of AWGN noise. L: the complete number of points in a certain sub-band.

Y_i: is a wavelet point in the certain sub-band.

2.3 Histogram Equalization Method

In this study, the histogram equalization technique has been involved in an image in the wavelet domain as one of the image enhancement techniques. Histogram equalization improves the active area of grey levels in a low-contrast image to cover the entire area. It is utilized to modify the distinction of an image by adjusting the density allotment of its histogram. Histogram equalization is completed by including a transformation process T(r), that can be expressed as the Cumulative Distribution Function (CDF) of a given probability density function (PDF) of grey levels in a given image. Histogram equalization is an image computations procedure that performs improving the observable occurrence of an image by equally distributing the density stages [Arora, 2018]. The histogram of an image can be evaluated as an approximation of its PDF; then the transformation process can be acquired. The operations of histogram equalization depend on using CDF. The CDF is an accumulative totality for entire possibilities found in its field. The discrete shape for the CDF is illustrated in the formula below [Mustafa, 2021]:

$$cdf(x) = \sum_{k=-\infty}^{x} P(k) \tag{10}$$

Asunder from the equalization feature, this approach presents a considerable difference in image brightness, i.e., its mean grey-level. That is, because of the invariant diffusion description of the resulting histogram, the CDF process turns the brightness of the resulting image to the median grey level [Nithyananda, 2016].

Histogram equalization is a method for modifying image density by improving contrast. Assume f is a presented image described as a kr by kc matrix of integer points vehemence varying from 0 to L-1 where L is the number of feasible density weights, usually 256. Assume p represents the naturalized histogram of f with a case for each feasible density. So:

$$P_n = \frac{number of pixels with intensity n}{total number of pixels} , n = 0, 1, ..., L-1$$
(11)

The histogram-naturalized photo *g* will be represented by:

$$g_{i,j} = floor\left((L-1)\sum_{n=0}^{f_{i,j}} P_n\right)$$
(12)

Where floor() approximated to the closest integer. This is identical to converting the points densities, k, : of f by the formula below:

$$T(k) = floor\left((L-1)\sum_{n=0}^{k} P_n\right)$$
(13)

The rationale for the conversion reaches from considering the densities of f and g as continuous arbitrary variables X, Y on [0, L-1] with Y represented by the formula below [Arora, 2018; Rajput, 2013]:

$$Y = T(X) = (L-1) \int_0^X P_X(x) dx$$
(14)

Where:

 P_X is the Probability Density Function of f, and T is the Cumulative Distributive Function (CDF) of X * (L-1).

3. THE PROPOSED ENHANCEMENT SCHEME

In this work, a mixture of the Multiresolution Discrete Stationary Wavelet Transform (SWT) and the Histogram Equalization techniques have been applied as a hybrid image enhancement approach. By using the MSE and the PSNR criteria the performance of the mixed methods was studied by this work for many scenarios trying to produce an improved outcome for the digital image enhancement suggested methods. During the implementation phase, the SWT involved utilizing many filters families for three experimental grayscale 8-bits images with the size of 256 x 256 pixels. The work used three levels of analysis the Multiresolution Discrete Stationary Wavelet Transform. The AWGN noise was added to the initial images with zero mean (m = 0) and with noise levels as $\sigma=15$, $\sigma=25$ to create the distorted images. the enhancement part that used SWT applied two kinds of threshold techniques the hard and the soft threshold. In our work, the name 'proposed technique' is

utilized to direct separately to the suggested techniques of the digital image improvement system. The improvement process is included the below actions that involved the digital image:

- 1-The system needs to state that 2D-SWT is implemented on the noisy image: For the first analysis layer in 2D-SWT the outcome is 4 sub-bands (A1, H1, V1, and D1), and for analysis, the second layer of 2D-SWT analysis the band A1 is the input for the wavelet transformation. While for the third level of the 2D-SWT analysis operation the input is the band A2 and obtain four bands as A3, H3, V3, and D3.
- 2-Involving the primary action of the denoising strategy as: If the denoising approach is the histogram equalization, then the histogram equalizer is implemented to all of the high frequencies' bands for all the analysis stages in 2D-SWT. But, if the denoising approach is a thresholding method, then a threshold weight is calculated for all of the high-frequency bands. Behind this level, and for each one of the high frequencies' bands, apply the comparison for each point in the sub-band with the threshold weight for this band. Results action for comparison operation depends on the type of the threshold method that has been used in this system.
- 3-Involving the synthesis process with the identical layers of the analysis process. The composition is used as 2D-ISWT (I is referred to Inverse); the latest sub-bands are reconstructed utilizing the denoising action to get a modified image called an enhanced result.
- 4-The PSNR is used for both the enhanced and the initial images to estimate the suggested image improvement approach.

Several scenarios are utilized in our work to implement the actions and the arrangement for utilizing the Histogram Equalization techniques and the Discrete Stationary Wavelet Transform. In all scenarios, the PNSR of the enhanced image is calculated and compared with the corrupted image.

In order to calculate the achievement of the suggested enhancement techniques, MATLAB software is employed. All of the used scenarios described as follows:

Scenario_1: Utilizing only the Thresholding Technique in Wavelet Domain

2D-SWT was utilized to organize the work zone for the threshold technique in this scenario. The scheme for this situation is shown in Fig.1 below. The improvement by employing the thresholding technique in the Wavelet domain describes the actions used in hard and soft (Sure shrink) threshold techniques. This method is called Proposed_1.



Fig. 1. The scheme of image enhancement method called Proposed_1, by thresholding technique in wavelet domain.

Scenario_2: Utilizing only the Histogram Equalization in Wavelet Domain

2D-SWT was utilized to organize the work zone for the implementing of histogram equalization procedure in this scenario. The scheme for this situation is shown in Fig.2. This method is called Proposed_2.



Fig. 2. The scheme of image enhancement method called Proposed_2, by histogram equalization in wavelet domain.

Scenario_3: Utilizing Thresholding Technique Before Histogram Equalization in Wavelet Domain

To implement this scenario of the suggested process, image enhancement was applied by two phases: applying the thresholding procedure on the corrupted image followed by applying the histogram equalization to all points of the same band in the wavelet domain. This scenario is called Proposed_3 and illustrated in the scheme of Fig.3 below:



Fig. 3. The scheme of image enhancement method called Proposed_3, by Thresholding Technique Before Histogram Equalization in Wavelet Domain.

Scenario_4: Utilizing Histogram Equalization Before Thresholding Technique in Wavelet Domain

To implement this scenario of the suggested process, image enhancement was applied by two phases: applying the histogram equalization on the corrupted image followed by applying the thresholding procedure on points of the same band in the wavelet domain. This scenario is called Proposed_4 and illustrated in the scheme of Fig.4 below:



Fig. 4. The scheme of image enhancement method called Proposed_4, by Histogram Equalization Before Thresholding Technique in Wavelet Domain.

4. EXPERIMENTAL RESULTS

Three of the 256 × 256 grayscale images displayed below in Fig. 5 were used as tested initial images in this study. The noise used in our work was of the form Additive White Gaussian Noise (AWGN), with a zero mean and a ratio as σ =15, and σ =25. Also, for creating the corrupted image, noise has been applied to an initial image. The hard and soft threshold approaches are used, and the soft threshold approach was represented by the SURE shrink.



Fig. 5. The test images.

Tables 1-2 below, indicate the PSNR significances for all scenarios of this work. All the cells labeled with a highlighted background in these tables describe the better outcomes.

The abbreviations are as follows:

Th.: Threshold method only.

Hisequ.: Histogram Equalization method only.

Th. then Hisequ.: Threshold method then Histogram Equalization.

Hisequ. then Th: Histogram Equalization then Threshold method.

TABLE 1 The Best PSNR Results for Applying Image Enhancement Techniques with Hard Threshold on All Images.

g	و		Cases					
Ima	Nois		Th	Hisequ	Th. then Hisequ	Hisequ thenTh		
Camera	15	PSNR	25.946	24.817	24.791469	24.603		
		Filter	rbio3.3	db44	db45	rbio6.8		
	25	PSNR	22.909	23.541	23.519129	23.535		
		Filter	rbio3.5	rbio2.8	rbio2.8	rbio2.8		
Butterfly	15	PSNR	25.605	23.486	23.464	23.445		
		Filter	rbio3.5	db44	db44	db44		
	25	PSNR	22.482	22.465	22.452	22.445		
		Filter	rbio3.5	coif3	bior3.9	rbio6.8		
	15	PSNR	26.464	24.401	26.843	26.806		
na		Filter	rbio3.5	bior2.6	bior2.6	rbio6.8		
Le	25	PSNR	23.439	20.280	25.593	25.163		
		Filter	rbio3.5	bior2.2	bior2.2	rbio6.8		

TABLE 2 The Best PSNR Results for Applying Image Enhancement Techniques with SURE Shrink as A Soft Threshold on All Images.

8	e		Cases					
Ima	Nois		Th	Hisequ	Th. then Hisequ	Hisequ thenTh		
Camera	15	PSNR	28.677	24.817	24.781	24.786		
		Filter	rbio1.1	db44	db44	db44		
	25	PSNR	25.778	23.541	23.523	23.535		
		Filter	rbio1.1	rbio2.8	rbio2.8	rbio2.8		
Butterfly	15	PSNR	28.230	23.486	23.451	23.446		
		Filter	bior1.3	db44	db44	db44		
	25	PSNR	25.184	22.465	22.445	22.447		
		Filter	rbio1.1	coif3	coif3	coif3		
	15	PSNR	29.208	26.812	26.812	26.813		
na		Filter	rbio1.1	bior2.6	bior2.6	bior2.6		
Le	25	PSNR	26.692	25.592	25.574	25.576		
		Filter	rbio1.1	bior2.2	bior2.2	bior2.2		

The figures 6-11, are showing the PSNR results for each image of the three test images and with both noise ratios 15 and 25 for all of the proposed methods of image enhancement system that are used in this work.



Fig. 6. The PSNR results for applying the enhancement methods on Camera image with noise=15, with the hard and soft threshold techniques.











Fig. 9. The PSNR results for applying the enhancement methods on Butterfly image with noise=25, with the hard and soft threshold techniques.



Fig. 10. The PSNR results for applying the enhancement methods on Lena image with noise=15, with the hard and soft threshold techniques.



Fig. 11. The PSNR results for applying the enhancement methods on Lena image with noise=25, with the hard and soft threshold techniques.

5. COMPARING WITH RELATED WORKS

The best PSNR values among the results of the proposed methods will be used for the comparison with several related works to indicate the contribution of the proposed techniques. The related works that will be used in the comparison are Mustafa (2021), Frezo (2020), Ramadhan (2017), and Sami (2016), and they will be titled Related1, Related2, Related3, and Related4 respectively.

The proposed techniques of image enhancement yielded better performance results and efficiency more than the related works, this can be shown and displayed in Table 3 below.

The PSNR Outcomes of The Comparison Operation						
Between the Suggested Scenarios and the Related Works						
For All Tested Images With Both Noise Ratios.						
	1					
T1	The image					
Ine	Camera				Lena	
Mathad	Cam	nera	Butt	erfly	Le	na

TABLE 3

T1	The image						
Mothod	Camera		Butterfly		Lena		
Methou	15	25	15	25	15	25	
Proposed	28.67	25.77	28.23	25.18	29.20	26.69	
Related1	24.68	23.51	-	-	26.59	25.24	
Related2	27.18	25.47	-	-	-	-	
Related3	25.12	23.38	24.70	22.82	26.54	24.61	
Related4	27.16	24.86	-	-	28.22	25.17	

6. CONCLUSION

In this work, a suggested technique was presented and implemented to the image corrupted by Additive White Gaussian Noise (AWGN). The suggested enhancement operation was performed using the combination of Histogram Equalization with a two-dimensional stationary discrete wavelet transform (2D-SWT) as a multi-resolution analysis technique in image processing with three levels of analysis to acquire modified results of the procedure of noise elimination. The performance of the suggested techniques was computed by utilizing the PSNR. Practical measurements show that the outcomes of the suggested approaches improved the PSNR by about (16.16%) concerning the achievements of the previous researches that were employed in the comparison operation, and the configuration of the image quality has also been enhanced in terms of edge keeping and greater noise reduction. For future works, the suggested process may be involved in other kinds of noise to terminate one or a combination of more than one type of noise in the images. Also, utilizing the enhancement technique with different types of threshold strategies and evaluating the implementation of these strategies.

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