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The Effectiveness of two Dimensional Haar Wavelet Image De-noising performance using Soft or Hard Thresholding Approach

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ABSTRACT

Image de-noising and restoration represent basic problems in image processing with many different applications including engineering, reconstruction of missing data during their transmission and enhancement ..etc. this work is aimed at developing effective algorithm for denoising image using new strategy algorithm of wavelet techniques ,by applying two dimensions wavelet transform using Haar wavelet. Wavelets are hierarchically decomposing mathematical tools. A noisy picture is sent to the Haar wavelet transform to create four decomposed bands(for each level), and the noise is then removed by applying a threshold to the resultant image band. Then, an inverse transform is used to provide a noise-reduced picture. Performance characteristics are improved by the suggested design in contrast to those of the current approaches.

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تأثير مويجة هار لإزالة الضوضاء عن الصور ثنائية الأبعاد باستعمال العتبة الحادة او الناعمة

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الملخص

إزالة الضوضاء و ترميم الصورمسائل أساسية في معالجة الصورفي العديد من التطبيقات المختلفة والتي تتضمن الهندسية منها استرجاع البيانات المفقودة اثناء ارسالها وتحسينها ... الخ.يهدف هذا العمل الى تطوير كفاءة خوارزمية إزالة الضوضاء وذلك بتطبيق التحويل المويجي ثنائي الأبعاد باستخدام تحويل مويجة(هار) لتقليل التشويش على الصور. المويجات هي أدوات رياضية متحللة بشكل هرمي. يتم إرسال صورة صاخبة إلى تحويل (هار) لإنشاء أربعة نطاقات متحللة(لكل مستوى) ، ثم تتم إزالة الضوضاء عن طريق تطبيق عتبة على نطاق الصورة الناتج. بعد ذلك ، يتم استخدام التحويل العكسي لتوفير صورة مخففة للضوضاء. يتم تحسين خصائص الأداء من خلال التصميم المقترح على عكس تلك الأساليب الحالية

I. INTRODUCTION

Signals are subjected to Fourier transformations in order to extract frequency information that is not easily accessible in the time domain shown in Fig. 1. A very excellent grasp of the frequency information included within the signal is provided by the signal's division into frequencies that are separated into uniform bands. Take a stationary signal, for instance. A signal is stationary when the frequency information it contains does not fluctuate over time [1] .

$$F(\omega)= \int_{-\infty}^{+\infty} f(t))\ e^{-j\omega t}\ dt \qquad (1)$$

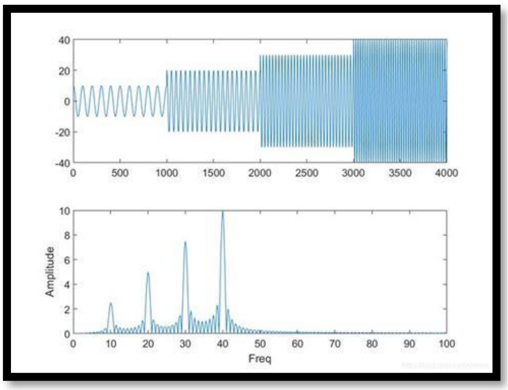

Fig. 1 Fourier transform

The quick Fourier transformation .The Short time Fourier Transform time resolution was addressed by the STFT. It provides a representation of the signal's timing and frequency. May presume that part of the non-stationary is stationary when using STFT . Fig.2 move a window function along the signal using one with a fixed length [1].

$$F(\tau,\omega) = \int_{-\infty}^{+\infty} f(t)w(t - \tau)\ e^{-j\omega t}\ dt \qquad (2)$$

Where w(t - τ) is window function. Fixed length of the window mean time -frequency resolution are fixed.

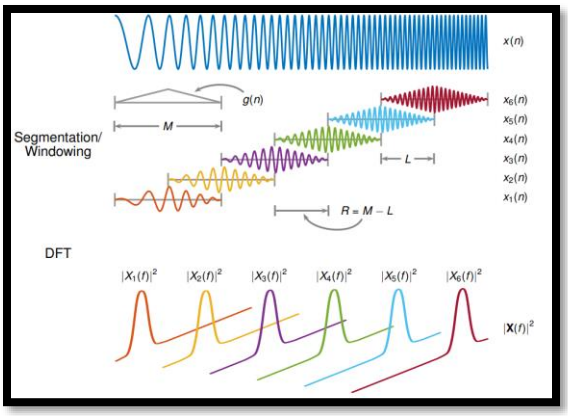

Fig. 2 The short time Fourier transforms STFT

The representation of a function by wavelets is known as the wavelet transform. A non-stationary signal is one whose frequency fluctuates over time. The wavelet transform was created to address certain issues with the short time fourier transform (STFT), and it may also be used to examine non-stationary signals. At all frequencies, (STFT) provides a consistent resolution. The wavelet transform employs a multi-resolution approach that allows for the analysis of various frequencies at various resolutions. The Wavelet Transform employs a method known as Multi-Resolution Analysis (MRA) to provide a variable time-frequency resolution. In this method, the smaller time interval windows are home to the higher frequency components whereas the larger time interval windows are the home of the lower frequency components. The wavelet transform may provide both time and frequency information at once, representing the signal in terms of time and frequency see equ (3) [2].

$$X_{WT}(\tau, s) = \frac{1}{\sqrt{|s|}} \int x(t).\psi^{*} \left(\frac{t-\tau}{s}\right) dt \qquad (3)$$

Where ψ the basis function or mother wavelet is (t). mother wavelet by scaling (compression) and translation (shifting). When a complex wavelet is present, the complex conjugate is employed, as shown by the asterisk (*). The position of the wavelet function as it is shifted across the signal is dependent on the translation parameter (τ). It thus matches the Wavelet Transform's time information. The scale parameter (s) is equivalent to frequency information and is defined as (|1/frequency|). Scaling causes a signal to either dilate (expand) or compress. Small scales (high frequencies) compress the signal and provide overall information about the signal, while large scales (low frequencies) expand the wavelet to reveal particular information concealed in the signal. The aforementioned analysis is highly helpful since in most real applications, high frequencies (low scales) only persist briefly whereas low frequencies (high scales) often last for longer periods of time [2]. There are many wavelet types can be shown in Fig. 3.

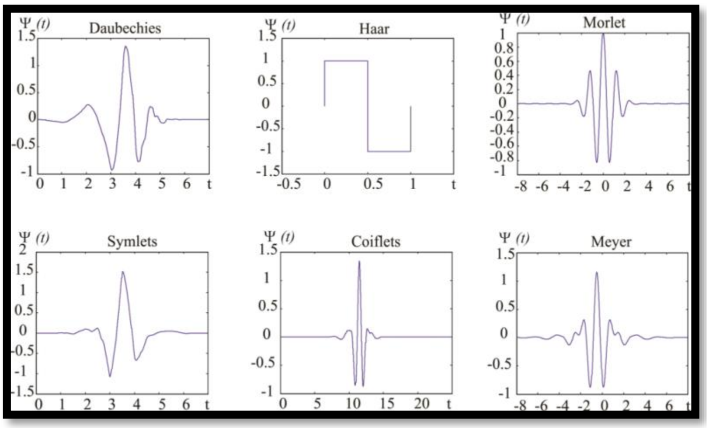

Fig. 3 Wavelet types

Continuous Wavelet Transform LL, LH, HL, and HH are the four sub-band coefficients that are produced by applying a fundamental Haar Wavelet to the signal. The L and H bands are generated by the equations (4) and (5), which define the 2x2 1D Haar wavelet [3].

$$y_L = \frac{A+B}{2} \qquad (4)$$

$$y_H = \frac{A-B}{2} \qquad (5)$$

where A and B are the data from distinct picture pixels.

The basic block diagram for both the forward and inverse 2D-DWT wavelet transformations is shown in Figure. 4 [7].

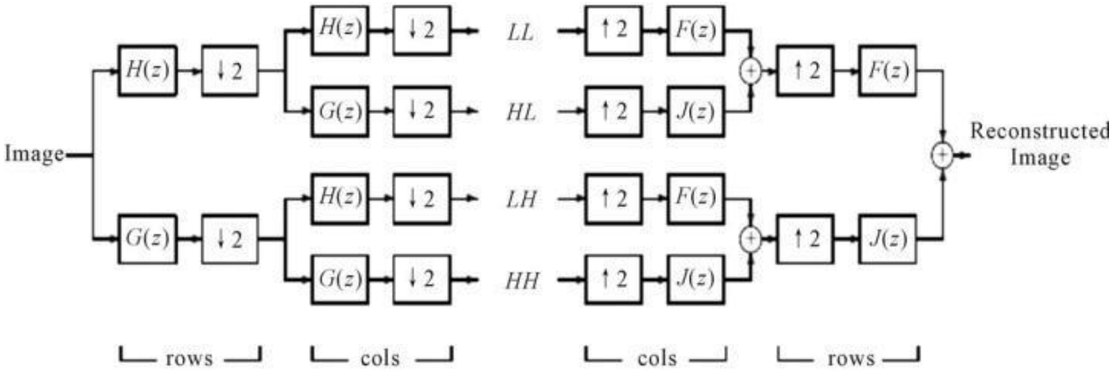

Fig. 4 Forward & Inverse 2D-DWT

It is exploring a new algorithm to improve the performance, spectral efficiency, and power efficiency and to reduce the complexity of communication system under the effect of the Additive White Gaussian Noise "AWGN" [4].
A newly developed tool for signal and picture processing is called a wavelet. They are used to examine the local aspects of complex signals at various time scales. Numerous fields, including geophysics, astronomy, telecommunications, video coding, and photography, find use for certain features of wavelet transform. The novel approaches for the analysis and synthesis of the signal employed in picture compression and de-noising are built on wavelets. These methods use the image data to get rid of undesirable noise [5].

STUDY OF THE LITERATURE

The enhanced noise reduction strategy that uses the Haar wavelet transform was presented by V] Sakthidasan [1].After applying the Haar transform to the ruined image, it will produce values that are the average as well as the difference between the neighboring coefficients. Hence, the values produced by the Haar transform are either positive or negative, depending on the variance of the random variables caused by noise. According to the findings, the suggested modified Neigh shrink approach works better than previous methods when the Wavelet transform is applied to the signal. This is measured in terms of PSNR and MSE.
Rajeswari, [3] offer a wavelet-based noise reduction approach over a picture that makes use of the threshold technique.
The Neigh Shrink approach that has been offered is one that is derived from the decimated wavelet transform and makes use of the universal threshold in addition to the size of the neighboring window. The proposed method has a significant flaw in that it always utilizes the same universal threshold, and the window size is always kept the same. According to the findings, the performance of the neighbor shrink approach that was developed is superior to that of other methods in terms of PSNR and MSE.
Al-Aboosi [4]. proposes a variety of approaches to threshold estimation for wavelet-based picture de-noising. Scale, the number of decompositions, and the noise variation all play a role in determining the adaptive threshold. The image can be recovered from a noisy image using the proposed semi-soft threshold that is based on sub band. According to the findings, the performance of the suggested approach is superior to that of other methods in terms of PSNR and MSE.
Pankaj Hedaoo and Swati propose several wavelet-based adaptive thresholding techniques for the purpose of picture de-noising in their work [4].

II. . PROPOSED ARCHITECTURE

Alfréd Haar, a Hungarian mathematician, developed the first DWT, the Haar wavelet, which is the most basic form of wavelet. A discrete signal is divided into two half-length subsignals using the Haar transform shown in Fig. 5. The average or trend is being tracked by one subsignal, while the difference or fluctuation is being tracked by the other subsignal (detail) [6].

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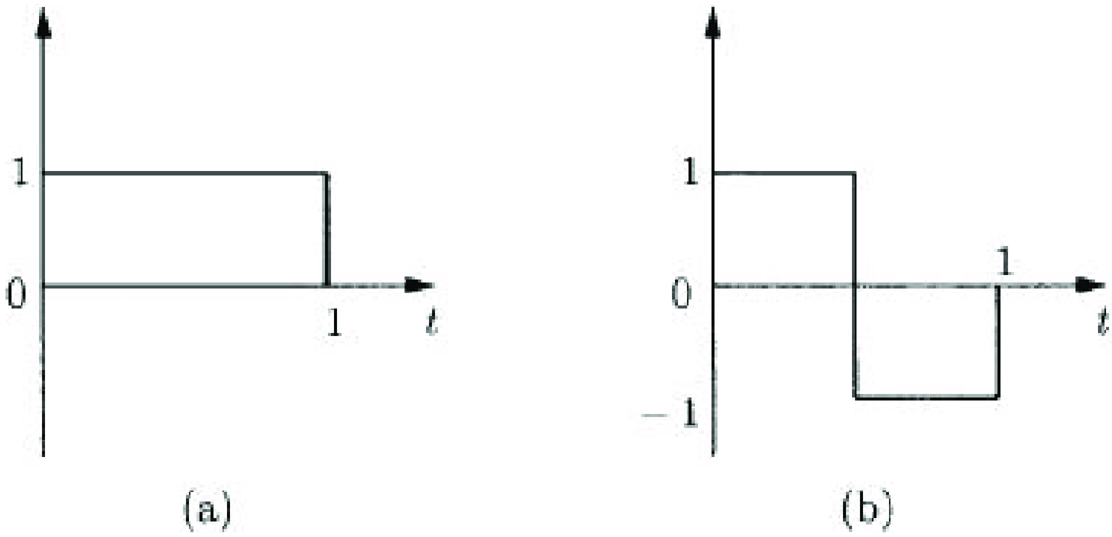

Fig. 5 Haar scaling and wavelet functions

$$\psi = \begin{cases} 1, if\ 0 \le X \ \le \frac{1}{2} \\ -1, if \frac{1}{2} \le X \le 1 \\ 0\ others\ cases \end{cases}$$

The advantages of the Haar wavelet include being simple, quick, memory-efficient (because it doesn't need a temporary array to compute), and precisely reversible without the edge effects that are a drawback of other wavelet transformations [7].

The recommended architecture's block diagram is shown in Figure 6. Photos of various sizes are first converted to 2D and reduced down to the usual 256 by 256 pixels. To produce all four coefficients (i.e., LL, LH, HL, and HH) where LL: Noisy Coefficients of Approximation, LH: Noisy Coefficients of Vertical Detail, HL: Noisy Coefficients of Horizontal Detail and HH: Noisy Coefficients of Diagonal Detail. The Haar wavelet transform is applied to the noisy input picture. In order to exclude negative values brought on by noisy components, a threshold is applied to the LH, HL, and HH bands. The number returned by computing PSNR shows that we are able to rebuild the picture such that there are less noise components present[5]. At level l decomposition, $3l + 1$ sub-bands are produced. A three-level Haar wavelet transform decomposes the original image into ten sub-bands [8].

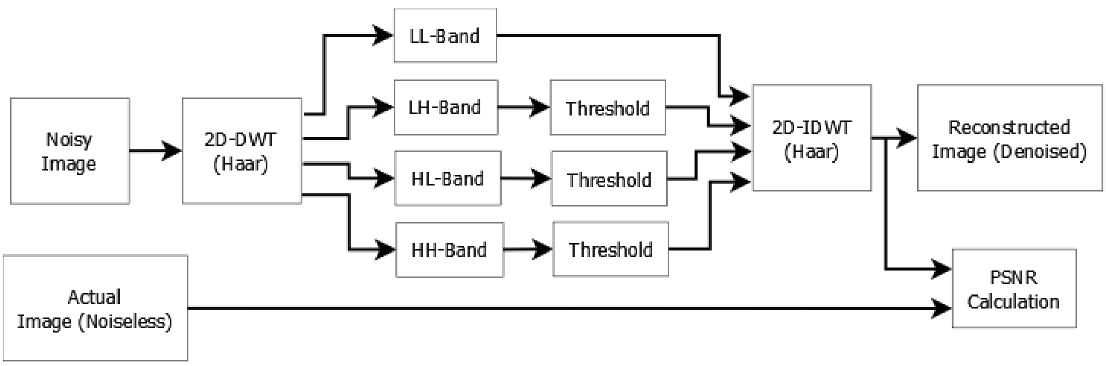

Fig. 6 shows a block diagram of the proposed image de-noising architecture.

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2.1 Threshold block

The threshold block is used to eliminate the negative values that the LH, HL, and HH noise components of an image create. These negative values just change the intensity value of an image; they don't include any information relevant to the image. Therefore, the threshold block will check the DWT block's co-efficients, and if any negative values are received, it will prevent transmitting any values by sending a value of 0. The process of decomposing data or an image into wavelet coefficients, comparing the detail coefficients to a predetermined threshold value, and then reducing the detail coefficients almost to zero to remove the influence of noise in the data is known as wavelet thresholding. The changed coefficients are used to recreate the picture (inverse discrete wavelet transform). When a wavelet coefficient is thresholded, it is compared to a preset threshold and, if its magnitude is less than the threshold, it is set to zero; otherwise, it is maintained or adjusted in accordance with the threshold rule. Thresholding makes a distinction between noise-related coefficients and those containing crucial signal information.

An important area of interest is the choice of a threshold. Because the denoising process typically creates smoothed pictures, decreasing the sharpness of the image, it plays a significant part in the reduction of noise in photographs. As a result, all coefficients with magnitudes larger than the chosen threshold value (σ) are left in place, while those with magnitudes lower than t are set to zero. Everywhere the coefficients are deemed to be irrelevant, a zone centered on zero is produced. Soft thresholding is the process of comparing coefficients to a threshold value and then shrinking those that exceed it toward zero. The following is its definition [9]. Figure. 7 shows the two thresholding methods, which are analytically represented as:

$$Hard\ threshold:\ \begin{Bmatrix} y = x & if\ |x| > \lambda \\ y = x & if\ |x| < \lambda \end{Bmatrix}$$

$$Soft\ threshold:\ \{y = sign(x)(|x| - \lambda)\} \qquad (6)$$

Where x is the input signal, y is the signal after the threshold, and is the crucial threshold value that determines whether a wavelet coefficient will be destroyed, reduced, or increased in value.

The following equation is the threshold block equation: (6) [10].

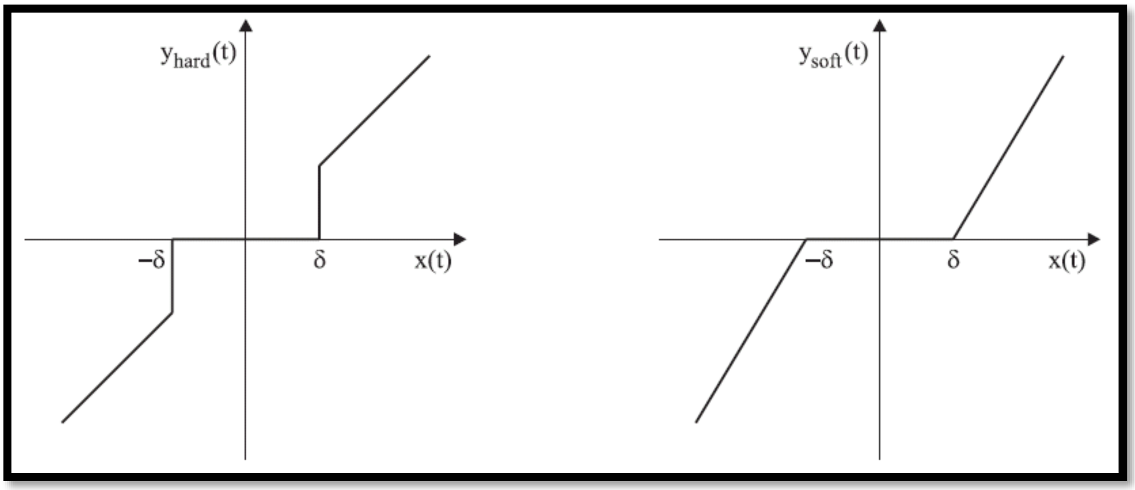

Fig. 7 soft and hard threshold

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III. SIMULATION RESULTS AND PERFORMANCE ANALYSIS

The suggested design is simulated in this part using the MATLAB R2018a (7.14.0.739) edition. Flowchart Shown in Fig.8

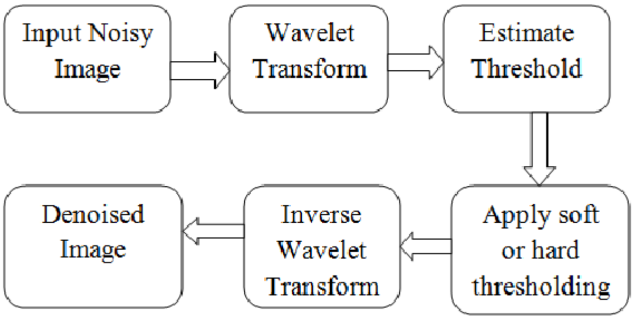

Fig.8 Software flowchart

3.1.Performance Indicators

In this section, the PSNR values of the original noiseless picture and the denoised image are compared using the following formula (7) [11].

$$PSNRB = 10\log_{10}\frac{255^2}{MSE} \qquad (7)$$

The term peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. Because many signals have a very wide dynamic range, (ratio between the largest and smallest possible values of a changeable quantity) the PSNR is usually expressed in terms of the logarithmic decibel scale.

Where, $MSE = \frac{1}{AB}\sum_{i=0}^{A-1}\sum_{j=0}^{B-1}[\,IN(i,j) - OP(i,j)\,]^2]$ (8)

where the input (noisy) image's pixel values are represented by IN(i,j).
The notation OP(i,j) denotes the values of the output (de-noised) picture pixels.
The picture has the following dimensions: AB (256x256) where A and B are the data from distinct picture pixels [12].

3.2. Image Output

Figure. 9 depicts the original, noisy, and de-noised images after using the suggested approach for de-noising.

cameraman
orginal image

noisy image

denoise image

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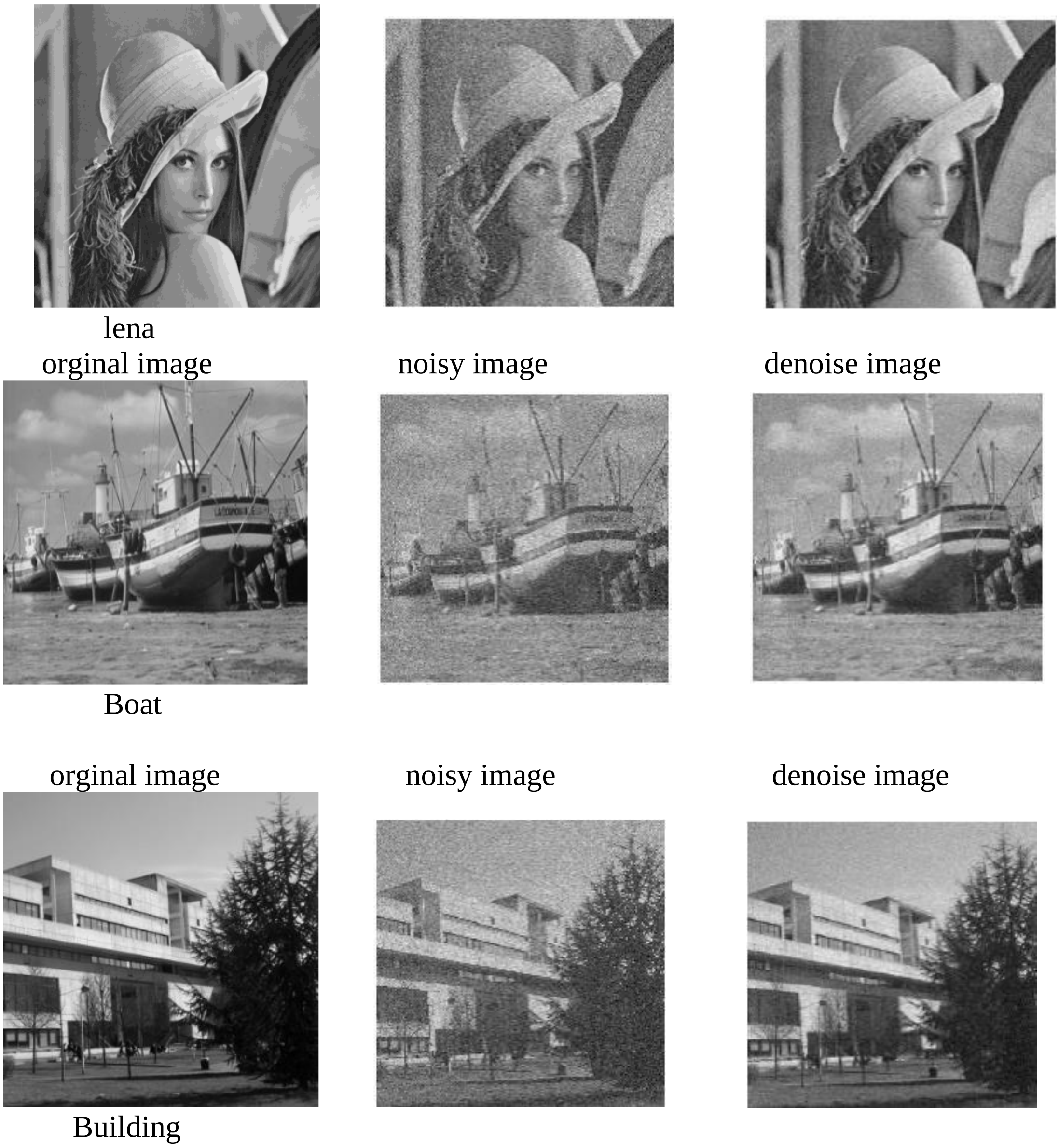

Fig.9 Images of the cameraman, lena, boat, and building after de-noising using the suggested approach.

RESULTS AND DISCUSSION

Employ a range of test images, encrypt the identical data into each image, and then compute PSNR values using equation (7) to assess the effectiveness of the proposed architecture. These results are tabulated in Table 1 and are subject to Gaussian noise with varying noise variance values. The global thresholding function is provided as, and the thresholding value (δ) is based on this function [13].

$$\delta = \sigma\sqrt{(2log\ (n))} \qquad (9)$$

Where (n) is the processed image's pixel count and (σ) is the noise's standard deviation.

The formula in (9) treats the variance of noise's value, (σ), as a constant throughout a range of time intervals. Because it's simple to know and use, this thresholding has an advantage when it comes to software implementation. This threshold estimator also makes sure that any sample in the wavelet transform when the essential function is precisely zero will be estimated as zero. By contrasting the denoised picture with the original image after the denoising process, performance can be evaluated.

TABLE 1 : PSNR Values for different images (Gaussian noise)

Image	Noise σ=20		Noise σ=40		Noise σ=60	
	PSNR (db) before denoising	PSNR (db) after denoising	PSNR (db) before denoising	PSNR (db) after denoising	PSNR (db) before denoising	PSNR (db) after denoising
Cameraman	22.01258	26.8758	16.0836	25.5642	12.5696	23.2598
Lena	22.1248	29.1489	16.1003	26.2846	12.5672	23.9850
Boat	22.1009	28.0164	16.1012	24.8172	12.5817	23.6415
Building	22.1044	25.4872	16.0840	22.2870	12.5532	21.5230

IV. PERFORMANCE COMPARISONS WITH EXISTING TECHNIQUES

This section compares the proposed approach's performance to the current technique in terms of PSNR values.

4.1. PSNR Comparisons

Table 2 displays the PSNR values for the proposed and current techniques. The previously given approaches by Rajeswari [3]., Ziyad and Shabana [5]., Aravindan and R. Seshasayanan [6]., and Abderrahim and Djouambi [8] serve as comparison points for the new methodology. It has been discovered that the proposed technique yields PSNR values that are higher than those generated by the currently used methods. Table 2 provides a comparison of the PSNR values obtained with the Proposed Method and those obtained with the Current Approaches.

TABLE 2 : Comparison of PSNR values of Proposed Method with the Existing Methods. (σ=40)

Image	Rajeswari [3]	Ziyad and Shabana [5]	Aravindan and R. Seshasayanan [6]	Abderrahim and Djouambi [8]	Proposed method
Cameraman	22.1280	23.4215	23.9254	24.46	25.5642
Lena	21.4554	22.2330	23.0014	25.0012	26.2846
Boat	19.6387	20.5541	21.2201	22.7254	24.8172
Building	20.1120	20.8001	21.4521	21.8001	22.2870

V. CONCLUSION

In this research work, efficient a Haar wavelet-based image denoising method. The suggested design could be able to reduce image noise more successfully than the present techniques by applies threshold. The reason for this is because most noise sources produce negative values in the LH, HL, and HH bands. The threshold then reduces this value to zero, making those values equal.

FUTURE WORKS

. The results are highly encouraging, and this concept may be used in the future to generalize another wavelet types for example Daubechies, Morlet...etc

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