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Novel Image Denoising using Series Structure of Wavelet Decomposition with Thresholding

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***Abstract** - Image denoising is the methodology to remove noises from images distorted by various noises like Gaussian, speckle, salt and pepper etc. This technology facilitate the imaging devices to a very large extent in some situations where noises is in the outer environment or distortions is created by dust particles, fog, or moistures etc. and effect of these noises can be reduced to enhance the visualization of images. So any work towards the improvement of denoising algorithm is always appreciable. In this paper an improved denoising algorithm is proposed with the series structure of wavelet decomposition with different symlet filter and different thresholding, and this structure significantly improve the results (i.e. PSNR) from previously implemented denoising algorithms.*

Keywords: **PSNR, Symlet Filter, Thresholding and Wavelet Decomposition.**

I. INTRODUCTION

Images are often corrupted with noise during acquisition, transmission, and retrieval in storage media. In a Photograph taken with a digital camera under low lighting conditions, many dots can be spotted. Fig. 1 is an example of such a Photograph. Appearance of dots is due to the real signals getting corrupted by noise (unwanted signals). On loss of reception, random black and white snow-like patterns can be seen on television screens, examples of noise picked up by the TV. Noise corrupts equally images and videos. The aim of the denoising algorithm is to remove such noise. Image denoising is required because a noisy image is not pleasant to view. Additionally, some fine details in the image may be confused with the noise. Many image-processing algorithms such as pattern recognition need a clean image to work efficiently. Random and uncorrelated noise samples are not compressible. These concerns underline the importance of denoising in image and video processing. The problem of denoising is mathematically presented as follows,

$$Y = X + N$$

Where Y is the noisy image, X is the original image and N is the AWGN noise with variance σ^2.The objective is to estimate X given Y. A finest estimate can be written as the

(a) Clean Boat Image (b) Noisy Boat Image
Fig. 1. Illustration of Noise in the Image

Conditional mean $\ddot{X} = E[X \mid Y]$. The difficulty lies in determining the probability density function $\rho(x \mid y)$. The purpose of an image-denoising algorithm is to find a best estimate of X. There are many denoising algorithms which have been published; still there is a scope for development.

GAUSSIAN NOISE

Gaussian noise is evenly distributed over the signal [21]. This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise rate. As the name indicates, this type of noise has a Gaussian distribution, that has a bell shaped probability distribution function given by,

$$G(f) = \frac{1}{\sqrt{2\Pi\sigma^2}} e^{-(f-a)^2/2\sigma^2}$$

Where f represents the intensity value, a is the mean or average of the function and σ is the standard deviation of the noise. Graphically, it has been represented as shown in Fig.2. When introduced an image, Gaussian noise with zero mean and variance as 0.05 would look as in Fig.3 [20]. Fig.4 illustrates the Gaussian noise with mean (variance) as 1.5 (10) over a fundamental image with a constant pixel value of 100.

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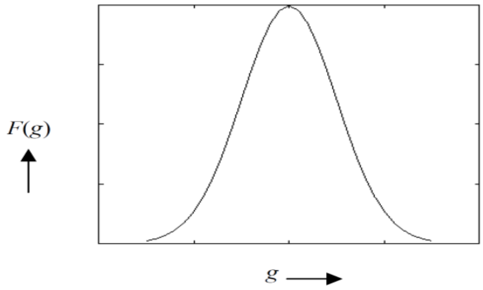


Fig.2: Gaussian distribution

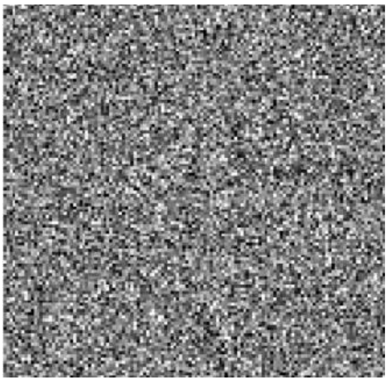


Fig. 3: Gaussian noise(mean=0, variance 0.05)

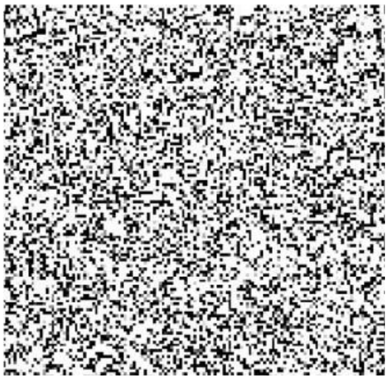


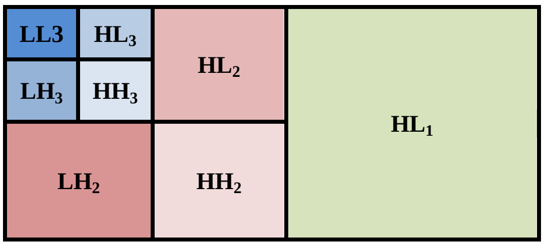
Fig.4: Gaussian noise (mean=1.5, variance 10)

II. WAVELET TRANSFORMS AND DENOISING

Wavelets are mathematical functions that analyze data according to scale or resolution [19]. They aid in studying a signal in different windows or at different resolutions. For example, if the signal is viewed in a large window, gross features could be noticed, but if viewed in a small window, only small features could be noticed. Wavelets provide some advantages over Fourier transforms. As they do a good job in approximating signals with sharp spikes or signals having discontinuities they could also be used for speech, music, video and non-stationary stochastic signals. Wavelets could be used in applications such as image compression, human vision, radar, earthquake prediction, etc. [19]. The term “wavelets” is used to refer to a set of orthonormal basis functions generated by dilation and translation of scaling function φ and a mother wavelet ψ [15]. The finite scale multiresolution representation of a discrete function can be called as a discrete wavelet transforms [18]. DWT is a fast linear operation on a data vector; length is an integer power of 2. Such transform is invertible and orthogonal, where as the inverse transform expressed as a matrix is the transpose of the transform matrix. The wavelet basis or function, different sines and cosines as in Fourier transform (FT), is quite localized in space. But similar to sines and cosines, the individual wavelet functions are localized in frequency.

WAVELET THRESHOLDING

Donoho and Johnstone [17] pioneered the work on filtering of additive Gaussian noise using wavelet thresholding. Wavelets play a major role in image compression and image denoising. Since our topic of interest is image denoising, the latter application has been discussed in detail. Wavelet coefficients calculated by a wavelet transform represent change in the time series at a exacting resolution. By taking into consideration the time series at different resolutions, it is then possible to filter out noise. The term wavelet thresholding is explained as decomposition of the data or the image into wavelet coefficients, comparing with the detail coefficients with a given threshold value, and shrinking such coefficients close to zero to take away the effect of noise in from the data. The image is reconstructed from the modified coefficients. This process is also called as the inverse discrete wavelet transform. All through thresholding, a wavelet coefficient has been compared with a given threshold and is set to zero if its magnitude is less than the threshold; other then it is retained or modified depending on the threshold rule. Thresholding distinguishes the coefficients due to noise and the ones consisting of important signal information. The choice of a threshold is an important point which plays a major role in the removal of noise in images because denoising most frequently produces smoothed images, dropping the sharpness of the image. Care should be taken for preserving the edges of the denoised image. There exist many methods for wavelet thresholding, which rely on the option of a threshold value. Some usually used techniques for image noise removal include Visu Shrink, Sure Shrink and Bayes Shrink [15, 16, 17]. Now let us focus on the three methods of thresholding mentioned earlier. For all these methods the image is first subjected to a discrete wavelet transform, which decomposes the image into may sub-bands. Graphically it can be represented as shown in Figure.5.



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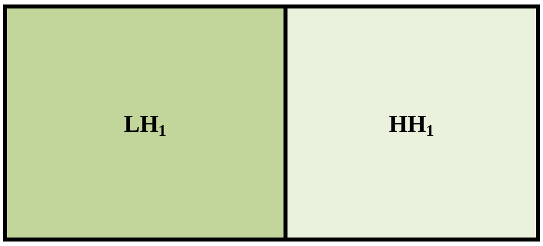

Fig.5: DWT on 2-dimensional data

III. PROPOSED METHODOLOGY

The proposed methodology followed in this work is presented here with the block diagram and flow chart of algorithm execution. Proposed methodology significantly improves the results compared to previous work. Which is explained in the next section of the paper (Fig. 6 shows the block diagram and Fig. 7 shows the flow chart)?

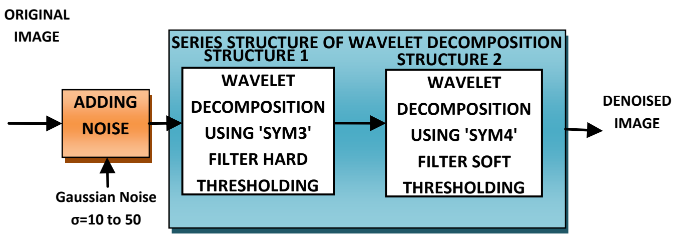

Fig. 6: Block Diagram of Proposed Methodology

In Fig. 6 block diagram of proposed methodology is displayed which has two main blocks i.e. first Gaussian noise of values sigma=10 to 50 is added to original input image and then second block denoising using wavelet decomposition is applied. The second block has the series structure of two wavelet decomposition filters 'sym3' with hard thresholding and'sym4' with soft thresholding is applied, and denoised image is obtained as the output of the system. In Fig. 3.2 flow chart of proposed methodology is shown. As the proposed denoising algorithm starts, an original image should be given as input for processing. The original image is attacked with different intensities of Gaussian noises (σ = 10 to 50) for checking the robustness and efficiency of denoising method. Then wavelet decomposition with two different orders of symlet filter ('sym3' with hard thresholding and 'sym4' with soft thresholding) are applied.

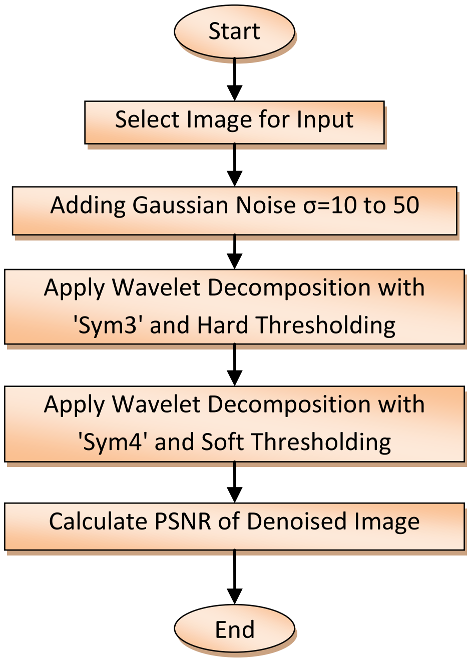

Fig. 7: Flow Chart of Proposed Methodology

After processing of noisy image with wavelet decomposition, denoised image is obtained and then PSNR is calculated which is better than previous methods.

IV. SIMULATION RESULTS

The simulation of proposed methodology as explained in previous section is simulated and performed on different images to check the authenticity of results on various images. The images flinstone, Barbara, lena, boats and peppers are taken for simulation. During simulation we have calculated peak signal to noise ratio (PSNR), that shows the Fig. of merit for denoising algorithms, means larger the value of PSNR of denoised image, more efficient the denoising method of all the results, we have displayed only one here. The Table I compare the PSNR values of proposed work with the previously applied methodologies, and have been found efficient in every manner of denoising.

TABLE I: Denoising results of Proposed Methodology on Gaussian Noise added Images

Technique	**Peak Signal to Noise Ratio (PSNR) db**														
Image	**Flinstone**					**Barbara**					**Boats**				
Sigma	**σ=10**	**σ=20**	**σ=30**	**σ=40**	**σ=50**	**σ=10**	**σ=20**	**σ=30**	**σ=40**	**σ=50**	**σ=10**	**σ=20**	**σ=30**	**σ=40**	**σ=50**
Previous Work	32.1	30.2	27.7	26.7	26.0	31.7	29.4	26.9	24.5	24.1	32.3	29.03	27.1	26.0	24.9
Proposed Work	**32.4**	**30.2**	**28.9**	**28**	**27.1**	**32.4**	**30.2**	**28.8**	**27.8**	**27.1**	**32.9**	**30.8**	**29.5**	**28.5**	**27.7**

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Image	Lena					Peppers				
Sigma	**σ=10**	**σ=20**	**σ=30**	**σ=40**	**σ=50**	**σ=10**	**σ=20**	**σ=30**	**σ=40**	**σ=50**
Previous Work	33.91	31.0	29.7	28.4	27.0	35.1	31.7	29.8	28.2	27.1
Proposed Work	**33.5***	**31.3**	**29.8**	**28.8**	**28.0**	**34.4***	**31.9**	**30.3**	**29.2**	**28.3**


a) Original Image


b) Denoised Image [σ=10, PSNR = 32.4 dB]

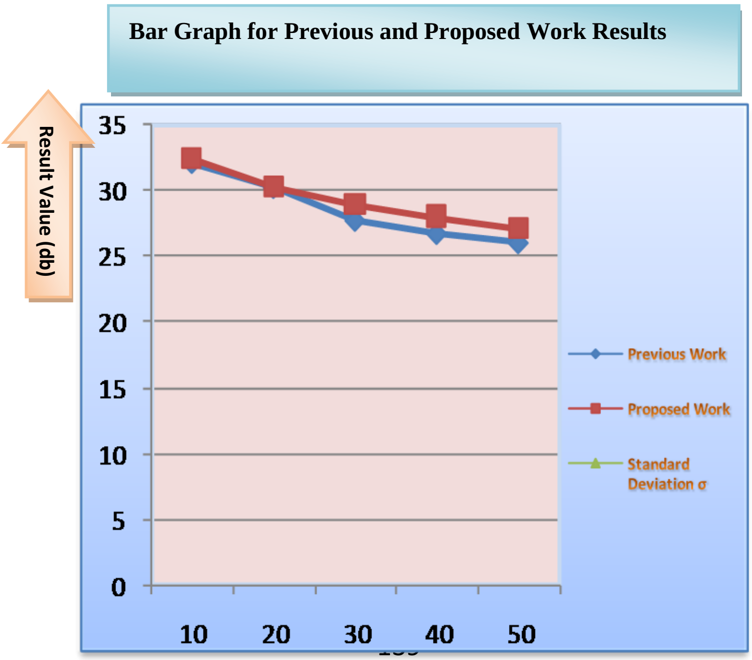

c) Denoised Image [σ=20, PSNR = 30.2 dB]


d) Denoised Image [σ=30, PSNR = 28.9dB]


e) Denoised Image [σ=40, PSNR = 28 dB]


f) Denoised Image [σ=50, PSNR = 27.1 dB]

Fig 8. Simulation Results-(a) Original Image, and (b) to (f) Denoised Image for Different Values of Gaussian Noise



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The above line graph shows the comparison between the PSNR values obtained with Previous and Proposed methods for different values of Standard Deviation(σ) for Input image(Flinstone 512*512).

The horizontal axis represents values of σ where as vertical axis shows the different values of PSNR corresponding to values of σ.

From this graph it is clearly visible that the proposed method shows improvement over previous method in terms of better Peak signal to noise ratio.

V. CONCLUSION AND FUTURE SCOPE

The simulation results of proposed methodology are explained in previous sections of this paper. The denoising algorithm is applied on various Gaussian noised images and the robustness of the results is clear from table of PSNR compared with the previous values. From the results we can say that the denoising method of this paper is efficient than the previously applied methodologies. In future more series combination of wavelet filters will give better results, and this concept can also be implemented with other decomposition techniques to get the better results.

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