The flow chart for Neigh shrink is as follows:

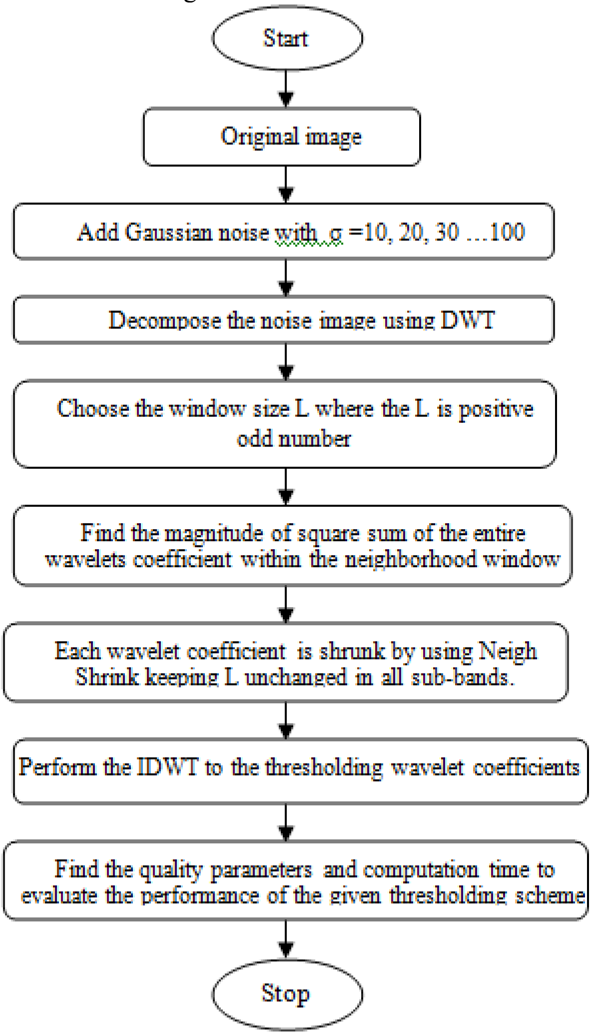

Figure 2: Flow chart for Neigh Shrink

3. Bayes Shrink

Bayes shrink is one of the most efficient existing methods of wavelet thresholding for the purpose of image denoising[18]. Bayes shrink was proposed by Chang, Yu and Vetterli [14][4]. It was proposed to minimize the Bayesian risk. It is different from other thresholding techniques as the results come from the Bayesian approach but not from soft or hard thresholding.

$$\sigma_s = \sqrt{\max(\sigma_W^2 - \sigma_s, 0)} \qquad (2)$$

where σ_s^2 is the variance of the signal.

The threshold value proposed in Bayes shrink is a function of noise variance and variance of noiseless data and is independent of the shape parameter [18]. The bayesian rule directly estimates the γ k without using soft or hard thresholding for a specific level [9]. A generalized gaussian distribution for the wavelet coefficients in each sub band is assumed. Then a threshold T is tried to find, that minimizes the Bayesian risk.

The flow chart for Bayes shrink is as follows:

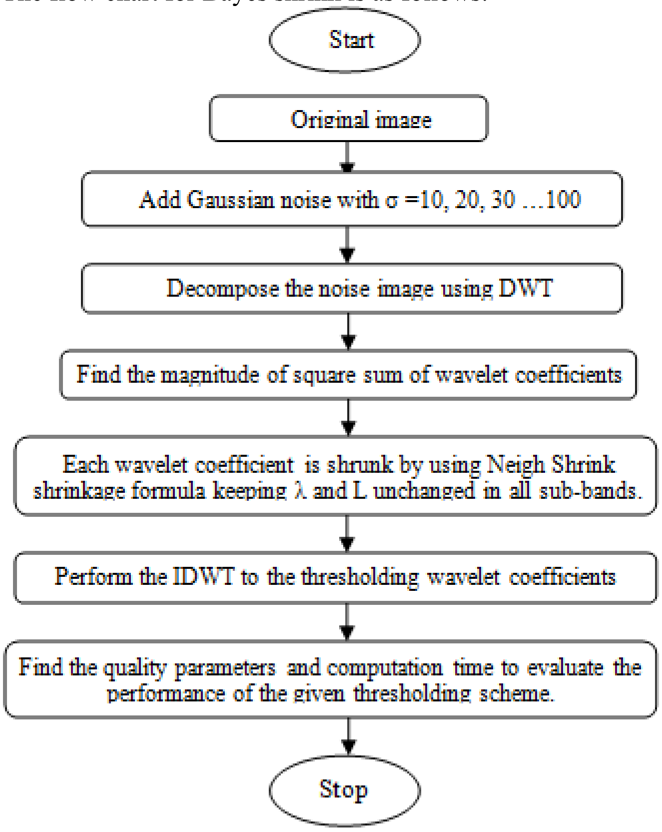

Figure 3: Flow chart for Bayes Shrink

4. Discrete Wavelet Transform

The non linear methods for denoising have gained the attention of the researchers these days. These methods are mainly based on thresholding the Discrete Wavelet Transform (DWT) coefficients, which have been affected by additive white Gaussian noise[12]. The DWT is basically the decomposition of the signal that provides better spatial and spectral localization. When a signal is decomposed, it is known as analysis, that in mathematical manipulation means discrete wavelet transform. When this decomposed signal is reconstructed, it is known as synthesis that mathematically means inverse discrete wavelet transform. Basically the denoising algorithms that use wavelet transform: calculating the wavelet transform of the noisy signal, modifying the noisy wavelet coefficients and computing the inverse transform using the modified coefficients.

DWT is basically a tool that separates data into different frequency components, then these are studied by matching the resolution to its scale[19].

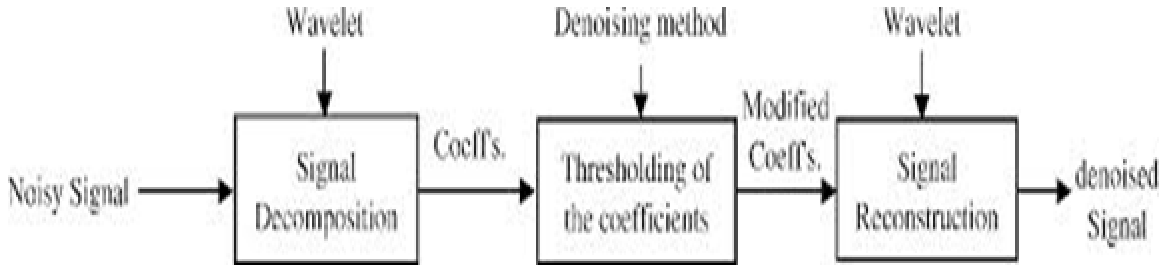

Figure 4: Diagram of wavelet based denoising

In the process of decomposition of an image by DWT, the transform coefficients are modelled as independent identically distributed random variables with generalized Gaussian distribution (GGD). The coefficients are then analysed on the basis of thresholding that can be either soft or hard thresholding. Some of the features of DWT are:

- Allows good localization in both time and spatial frequency domain.
- Transformation of whole image introduces inherent scaling.
- Better identification of what data is important according to human perception.

5. Proposed Method

In the proposed method, I have combined the Neigh shrink and Bayes shrink to get a more productive result, i.e. to get more denoised image. This hybrid of the thresholdings is applied on the image using the discrete wavelet transform. The methodology of the DWT based image denoising has the steps as shown in figure 4[6]:

- The noisy image is transformed into an orthogonal domain by discrete 2-D wavelet transform.
- Then hard or soft thresholding is applied on the noisy detail coefficients of the wavelet transform.
- The denoised image is obtained by applying inverse discrete wavelet transform.

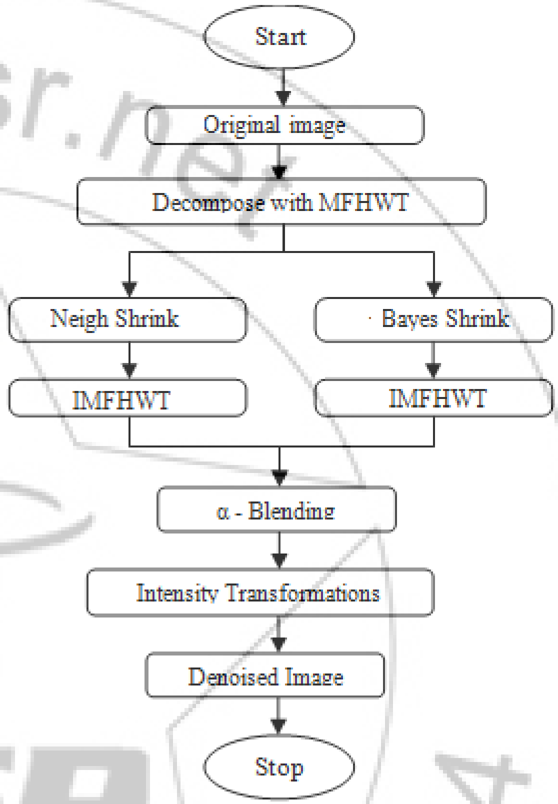

Figure 5: Flow chart for the proposed method

In this method, the original grayscale image is first corrupted by Gaussian noise. The image is then decomposed. For the decomposition, the discrete wavelet transform is used. It decomposes the image to four different frequencies namely approximate, horizontal, vertical and diagonal (a, h , v ,d).

- Approximation: includes information of the average of the image.
- Horizontal: includes information regarding the horizontal edges/details of the image.
- Vertical: includes information regarding the vertical edges/details of the image.
- Diagonal: includes information regarding the diagonal details of the image e.g. corners.

For this decomposition there are present different wavelets like haar, daubechies etc. But here, MFHWT (modified fast haar wavelet transform) has been used. The MFHWT is an enhancement of haar wavelet.

The MFHWT reads the image as a matrix. to all the rows and columns, MFHWT is applied. From the average and difference of nodes of previous level, the approximate and detail coefficients are counted. The process is called wavelet decomposition and the detail coefficients are called wavelet transform coefficients. The decomposed image is then passed through neigh shrink and bayes shrink which convert the image into a set of frequencies by taking a threshold value and changing the values below this threshold to 0. This cleans out the unnecessary details, which are considered as noise. For the reconstruction of the image, the inverse of MFHWT is considered that is also called wavelet reconstruction. It changes the set of frequencies into a proper image. Here, we get two images, one from neigh and another from bayes after reconstruction. So to merge these into a single image, alpha blending is used. Further to enhance the contrast of image, the intensity transformations are used. Goal is to modify pixel intensity to improve the visibility of objects of interest in an image. And hence, we get the denoised image. The results are compared on various quality parameters like PSNR, CNR, entropy and standard deviation.

6. Results and Discussions

The experimental results have been carried on different images. Every image has been corrupted by Gaussian noise. The results show that the hybrid of two very good denoising methods i.e. Neigh and Bayes shrink gives better output than the result given by them solely. The tables below show the results for 3 different test images.

Table 1: Results for test image Lena

Type of method	*Quality parameters*			
	PSNR	*CNR*	*Entropy*	*Standard Deviation*
Neigh	23.853	80.920	0.458	47.570
Bayes	24.797	65.744	0.454	46.889
Hybrid	28.763	108.639	5.646	51.545

Table 2: Results for test image Boy

Type of method	*Quality parameters*			
	PSNR	*CNR*	*Entropy*	*Standard Deviation*
Neigh	23.937	57.351	0.386	61.094
Bayes	25.019	41.770	0.352	60.567
Hybrid	28.484	86.617	5.517	65.374

Table 3: Results for test image Dog

Type of method	*Quality parameters*			
	PSNR	*CNR*	*Entropy*	*Standard Deviation*
Neigh	24.468	91.668	0.148	55.166
Bayes	26.059	59.027	0.142	54.569
Hybrid	29.721	107.591	5.162	59.385

Original image   Noisy image

Figure 6: Example of test image Lena when tested with proposed method.

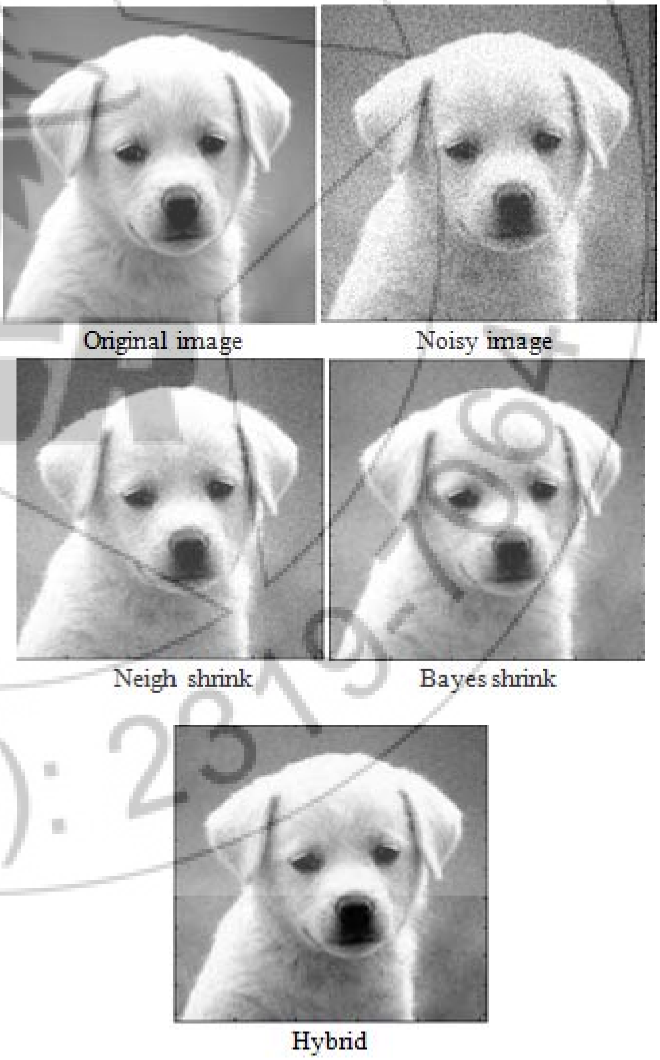

Figure 7: Example of test image Dog when tested with proposed method.

7. Conclusions and Future Scope

The paper represents a new technique for image denoising especially for the image corrupted by Gaussian noise, which is the most common noise amongst all. It is very clear from the paper that blending of two types of thresholding techniques give a better output. The wavelet transform proves to be an effective technique in denoising the images. The tables show that the hybrid gives higher values for the quality parameters than the both.

But we cannot deny the fact that this study of image denoising will never end. So for better results, we can always try for new techniques. Thus in future, we can try to merge some other thresholding techniques with this proposed method to check for better results.

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