Improved Spatially Adaptive Thresholding Technique for Noise Reduction

Thesis submitted in partial fulfillment of the requirements for the award of degree of

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in

Software Engineering

Submitted By

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Certificate

I hereby certify that the work which is being presented in the thesis entitled, "***Improved Spatially Adaptive Thresholding Technique for Noise Reduction***", in partial fulfillment of the requirements for the award of degree of Master of Engineering in *Software Engineering* submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of *Dr. Sushma Jain* and refers other researcher's work which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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Abstract

Noise suppression in images is a difficult task and anomalous. The selection between the preservation of actual image quality and noise reduction elements must be made in a way that it enhances the diagnostically applicable image content. For example in the medical images, specialists generally do not have the biomedical expertise to judge the demonstrative importance of the De-noising results. For instance, in ultrasound pictures, dot clamor may contain data valuable to medicinal specialists that the spotted composition makes troublesome for an analysis.

Similarly, Gaussian noise in an image captured by a camera at the remote or local server may have noise due to signal attenuation, dust or the poor exposure of the image to light. Also, such pictures show compelling variability and it is important to optimize with reduced CPU overhead. This persuades the development of efficient denoising methods and robust that is appropriate to different circumstances, instead of being ideal under particular conditions.

In this thesis, we have proposed robust technique that adjusts to different levels of Gaussian image noise and detects it using spatially adaptive soft thresholding technique. A Gaussian deviation in X direction parameter is used to adjust the preservation of pertinent points of interest of the image against the level of noise reduction. A demonstration of its helpfulness for denoising and upgrade of the pictures is done in MATLAB environment with the addition of Gaussian noise.

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Human vision is a perplexing procedure that requirements many segments of the brain and human eye to cooperate. The vision sense is a standout amongst the most key faculties for development and human life. Human utilizes the visual organs to see or get visual data, to see, i.e. to comprehend it and after that reason deductions from the apparent data. The circle of picture handling concentrates on mechanizing the way toward gathering and preparing visual information into the important signal. The way toward getting, handling, controlling and breaking down visual data by computerized is called digital image processing.

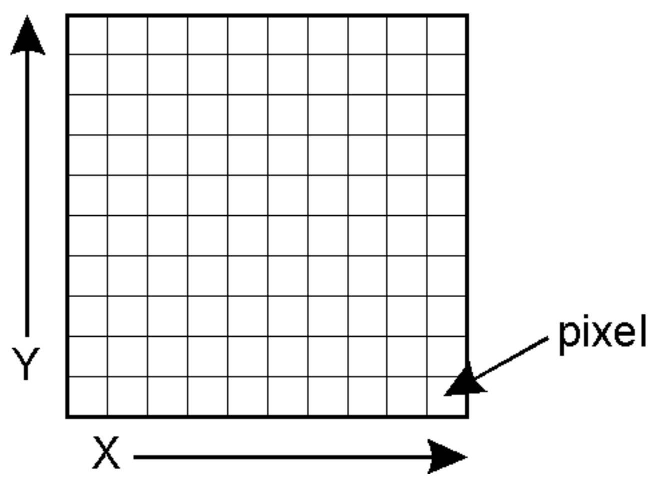

Fig. 1.1: Image representation

An image is always described by using a 2-D function F [14].

$$F= f\ (x, y) \tag{1}$$

Where x and y are represent the spatial coordinates of the axes. Volume of f at any arbitrary pair of coordinates let's say (x; y) is termed intensity (gray value). Then again, spatial directions and sufficiency qualities are all limited and discrete amounts. Such image is termed digital image.

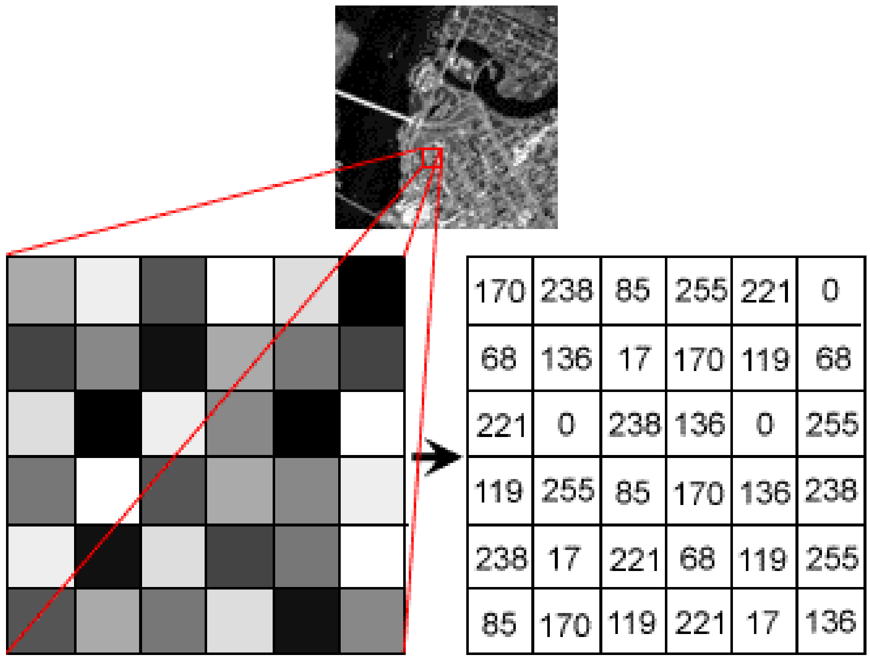

Fig. 1.2: Intensity of image pixels

Digital image processing is divided into different types based on various ways:

- Input and output are in the form of images.
- Inputs can be images though outputs are properties from such images.

The distinct image processing functions based on basis of two above category is represented below.

- Image Capturing
- Image Enhancement features
- Color Image Processing
- Image Restoration Process
- Object Recognition
- Multi-resolution Processing
- Segmentation
- Morphological Processing
- Compression
- Representation and Description

For some functions, the inputs and outputs are in the form of images however for the staying three the yields are only the attributes from the particular info pictures. With special case of procedure of image obtaining and showing the greater part of the picture, preparing capacities are executed essentially in software. Image preparing has been portrayed by some specific arrangements and thus the procedure which functions admirably in a specific region can be considered as lacking in another zone. The particular arrangement of the specific issue will require a ton of innovative work.

Types of digital image processing [5], referred to over, my work manages work of image restoration after denoising.

1.1 Noise

Image noise is an artifact which is random, mostly unwanted, variations can be found with brightness or color information about image. Digital image noise may generate electronic noise or from film grain in input devices (Web camera) circuitry and sensor. Image noise is highly detectable in image layout having low signal strength, like shadow regions or less exposed parts of the images. Large level of noise is always unwanted; however, there are situations where lesser levels of noise get valuable, let us take a case to prevent discretization artifacts (additionally termed posterization or color banding). The noise which is included intentionally for such work is termed flap.

1.2 Types of Noise

There are seven types of noise that are explained further.

1.2.1 Salt-and-pepper noise

Also called "impulsive" noise or Fat-tail circulated is termed salt-and-pepper noise. A picture which contains Fat-tail circulated noise comprises of dim pels in brighter parts of the image and splendid pixels (like white) in dim districts. This specific sort of is introduced by dead pixels in the image or image conversion errors, transmission errors, etc.

1.2.2 Shot noise

The prominent clamor in the lighter pixels of a picture which is mostly generated using an image sensor like the camera is typical which is generated by statistical quantum fluctuations, also known as, changes in the count of photons received by the sensor at a said presentation level, this clamor is termed as photon shot clamor.

It has a worth which is the root-mean-square esteem which thus is corresponding to the square root of the picture force, the noise at numerous pels are autonomous of each other. Shot noise takes after a basic standard of Poisson conveyance, which is almost similar from Gaussian distribution. Further in photon shot noise presence of additional clamor from dim spillage current in picture sensor; otherwise called "dull shot clamor" [3]. Dull current is biggest at "hot pixels" inside the picture sensor gadget; the changing dim charge in regards to ordinary and hot pixels which are subtracted (utilizing "dim casing subtraction"), leaving just shot clamor, or the irregular segment, of spillage, if the dim casing evacuation is not completed, or if introduction time is too long that hot pixel charge surpasses direct charge limit, noise will turn out to be more than simply the shot clamor yet hot pixels shows up as spike clamor.

1.2.3 Gaussian noise (Amplifier noise)

The basic representative of Gaussian clamor is added substance in nature, an amplifier which is autonomous at every pel and free of sign power, which is created basically by J.Nyquist clamor, which incorporates what originates from reset noise of capacitors ("kTC noise"). In shading image cameras where we have enhancement is utilized more as a part of blue shading direct as opposed to in red or violet channel, we can have more noise present in the blue segment [3]. Gaussian noise is most common "read noise" of picture sensor, which is nearness of steady clamor level in separate dim spaces of the picture.

1.2.4 Uniform noise (Quantization noise)

The noise generated due to quantizing pixels of a picture acquired by a sensor to various different levels called quantization clamor; having an approx. uniform dispersion, and might be subject to the signal, despite being sign autonomous if however clamor sources are sufficiently huge bringing about flapping, or if flapping is independently connected to the image[16].

1.2.5 Film grain

The noise in the form of grain on photographic film is signal-dependent noise. They react according to the intensity of the exposure. That is, on the off chance that film grains have been consistently dispersed, and if every grain is having an equivalent and freewheeling probability to develop a dim silver grain in the wake of retaining the photons of light from the source, then the quantity of dull grains around there is irregular with one binomial circulation. Whereas in regions where the probability of circulation is less, this specific dissemination will be near great Poisson dispersion of said uniform noise. A basic Gaussian circulation is additionally adequate. This kind of film grain has been typically viewed as about isotropic clamor source, which is exacerbated by dispersion of the silver halide grains present in film additionally being arbitrary.

1.2.6 Non-isotropic noise

A few noises are introduced and detected with respect to the orientation of the pixels in images. Consider an example where image sensors sometimes generate noise in the row or column form. In the film the marks go about as a case of the non-isotropic noise. These noises are generally introduced due to poor sensor quality.

1.2.7 Image noise reduction

Noise can't be eliminated without loss of data in the type of pixel details. All things considered, noise-reduction algorithms are produced to lessen the noise without debasing the picture data way too huge.

Removing noise from the image is possible only if there is the availability of some detailed information about the image. The information is used by different parameters of the algorithm to recover signal and lower the noise. A number of noises in the one-dimensional transient signal follow the law of Gaussian distribution. An algorithm like Bayes estimator [24] reduces the risk of optimal estimation or the minimax estimator implements simple layout for estimation. These are commonly used estimators in noise estimation.

In the use, the risk should be as minimal as possible. Donoho and Johnstone [24] made a breakthrough by proving the fact that threshold estimator has a minimal risk which is very close to lower bound. So, threshold estimation was studied in detail and has been improved by many researchers.

1.3 Thresholding Methods

1.3.1 Universal Thresholding Methods

Johnstone and Donoho was invented universal thresholding method [24]. The basic method can be expressed as follows:

$$\lambda_{universal} = \sigma\sqrt{2\log(n)} \qquad (2)$$

where n denotes the aggregate no. of information focuses, σ means the standard deviation of the commotion force which is generally obscure and gets typically changed by a vigorous appraisal, $\hat{\sigma}$ such that middle supreme deviation of wavelet coefficients at finest level (j = log(n) - 1) is.

$$\hat{\sigma} = median(|d_{j-1,k} - median(d_{j-1,k})|) \qquad (3)$$

By using universal threshold leads to biggest edges and therefore an estimate of regression function alongside the moderately high level of the flowing.

1.3.2 Sure Thresholding Method

Let Y ~ Np (μ, F) be the multivariate Gaussian perceptions where mean vector is represented by μ and the corner to corner covariance lattice by F, shows below:

$$\hat{\mu}(Y) = Y + g(Y) \quad (4)$$

Where $\hat{\mu}$ (Y) is connected with a specifically altered estimator of μ and $g = (g_t)_{t=1}^{p}$ is one capacity from R^p into R^p which is expected that it is pitifully differentiable, then

$$E_\mu \left\| \hat{\mu}(Y - \mu) \right\| = p + E_\mu \left\{ \left\| g(Y) \right\|^2 + 2\nabla.g(Y) \right\} \quad (5)$$

where
$$\nabla.g = \sum_{i=1}^{p} \frac{\partial}{\partial x_i} g_i \quad (6)$$

The point of Johnstone and Donoho [24] was to implement Stein's outcome utilizing delicate thresholding technique.

In this case:

$$g(x_i) = \begin{cases} -x_i & if \ \left| x_i \right| \le \lambda \\ -\lambda & if \ \ x_i > \lambda \\ \lambda & if \ \ x_i < \lambda \end{cases} \quad (7)$$

Then:

$$SURE(\lambda_J, d_{jk}) = p - 2.\#\left\{ i : \left| x_i \right| \le \lambda \right\} + \sum_{i=1}^{p} (\left| x_i \right| \wedge \lambda)^2 \quad (8)$$

is an unbiased risk estimatation, which means:

$$E_\mu \left\| \hat{\mu}^{(\lambda)}(Y) - \mu \right\| = E_\mu SURE(\lambda, x) \quad (9)$$

SURE threshold can be represented as:

$$\lambda_{j,SURE} = \arg_{0 \le \lambda \le \sqrt{2\log n}} \min(\lambda_J, d_{jk}) \quad (10)$$

1.3.3 Hierarchy of Image Denoising Methods

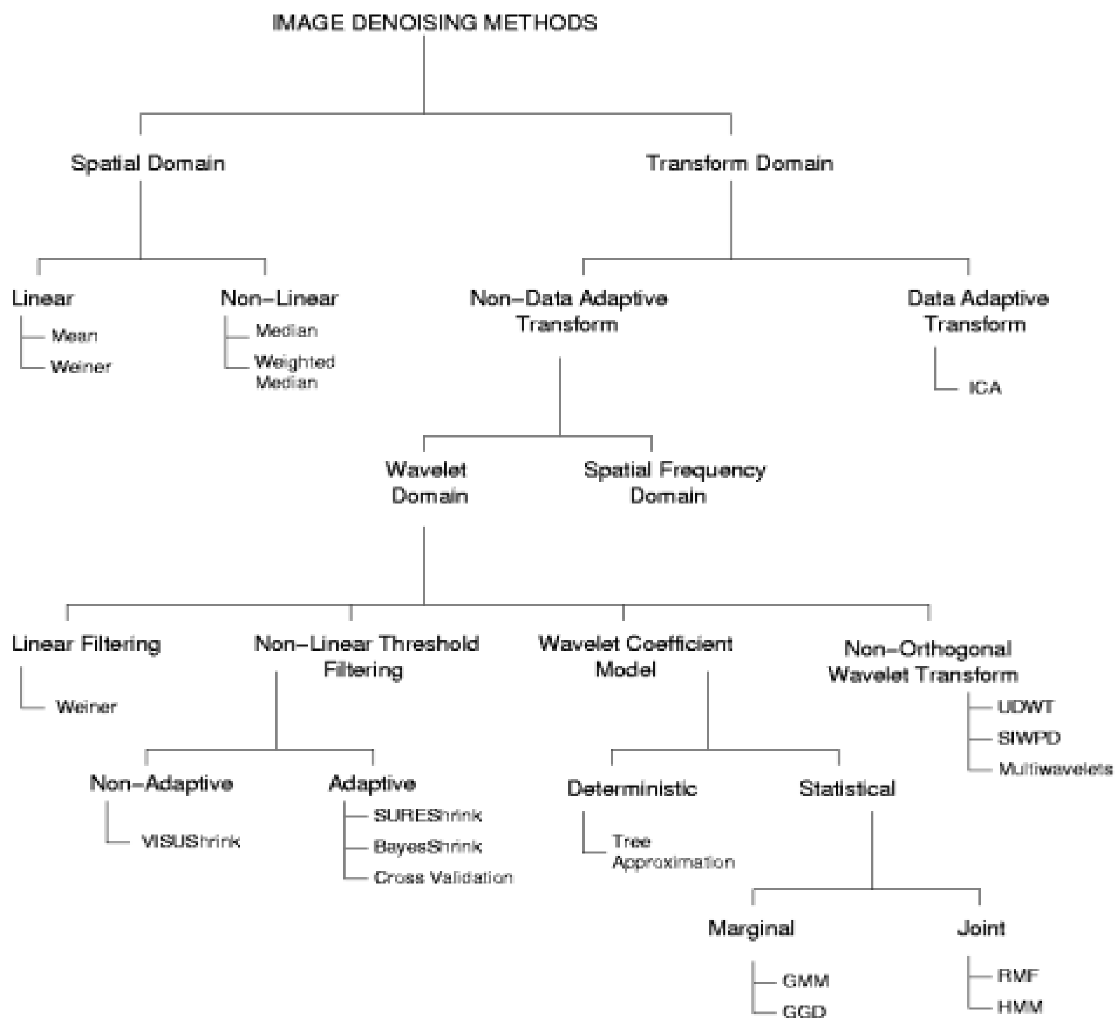

Fig. 1.3: Image Denoising Methods

1.3.4 Threshold Filtering using Wavelet Transform

The most commonly used technique as a part of denoising is Wavelet Change. It is non-straight coefficient thresholding based technique that exploits sparsity in wavelet change. Wavelet Change maps repetitive sound sign area to background noise change space.

Therefore, when signal vitality turns out to be exceedingly moved into fewer coefficients in change domain however clamor vitality does not. It is most essential standard in which division of sign from clamor is finished. In this process, littler coefficients are expelled while remaining are left as it is known as the Hard Thresholding [5]. This technique produces something called spurious blips, also called artifacts, in images due to unsuccessful endeavors of expelling respectably high noise coefficients. To overcome bad marks of hard thresholding, wavelet transforms utilizing delicate thresholding likewise presented as a part of [5]. In this method, coefficients over as far as possible are lessened by the total estimation of limit itself. In the same manner to delicate thresholding, some distinctive methods of the limits are Garrote thresholding and the semi-delicate thresholding [6]. Optimal threshold selection is one of the important non-versatile approach or versatile approach.

1.3.4.1 Non- Adaptive Threshold

VISUShrink is a general and non-versatile threshold choice technique, which depends entirely on the number of information focuses. It has an asymptotic identicalness recommending that the best execution regarding the MSE when a number of pixels achieve infinitely. VISUShrink is to a great extent known not excessively smoothed pictures since its limit decision may be unjustifiably high because of its reliance on the number of pixels in the picture.

1.3.4.2 Adaptive Threshold

Cross Approval method replaces the wavelet coefficient with weighted normal of neighborhood coefficients in order to minimize GCV (Generalized Cross Validation) function which gives an ideal limit to every last coefficient esteem. BayesShrink minimizes Baye's risk Estimator capacity by expecting the Summed up Gaussian before and along these lines producing information versatile limit. Baye's Shrink is proved to be more efficient than SUREShrink method.

1.3.5 BayesShrink Thresholding

It is the versatile threshold utilized for picture denoising through wavelet delicate thresholding. Mostly effective for the images which are corrupted by the Gaussian white noise. Produced by the summed up Gaussian circulation, threshold for wavelet coefficients in each subband tries to discover edge E which minimizes Baye's Risk. The reconstructed image created by utilizing BayesShrink is clearer and smooth after that one acquired utilizing the SureShrink. The essential model can be communicated as takes after:

$$X = Y + V \tag{11}$$

Where X is transformed degraded image by wavelet coefficients, Y is wavelet change of unique picture and V speaks to wavelet change of noise parts taking after Gaussian circulation M (0, σ_v^2). Since V and Y are said to be commonly free, variances σ_x^2, σ_y^2 and σ_v^2 of x, y and v is represented as

$$\sigma_x^2 = \sigma_y^2 + \sigma_v^2 \tag{12}$$

The σ_v^2 can be calculated from first decay level corner to corner subband a(n) by strong and exact middle estimator.

$$\sigma_v^2 = \left[\frac{median(|a(n)|)}{0.6745}\right]^2 \tag{13}$$

where σ_v^2 is noise variance.

The variance of the sub-groups of corrupted picture pixels gets spoke to as:

$$\sigma_x^2 = \frac{1}{M}\sum_{m=1}^{M} A_m^2 \tag{14}$$

where M is a total number of the wavelet coefficient in that individual sub-band, A_m is wavelet coefficients of the sub-band under thought. BayesShrink thresholding method plays out the delicate thresholding, along the versatile information driven, sub-band and the level ward close ideal limit given by [18]:

$$T_{BAYES} = \begin{cases} \dfrac{\sigma_v^2}{\sigma_y}, & if\, \sigma_v^2 < \sigma_x^2 \\ \max\{|A_m|\}, & otherwise \end{cases} \tag{15}$$

where

$$\sigma_y = \sqrt{\max(\sigma_x{}^2 - \sigma_v{}^2, 0)} \tag{16}$$

For the situation, where $\sigma_v^2 > \sigma_y^2$, σ_x is taken to be zero, this implies TBAYES→∞, or, practically speaking, TBAYES = max(|A_m|), and all coefficients are set to zero.

1.4 Thesis Outlines

Thesis is organized into five chapters. A brief review of each chapter is as follows:

Chapter 2: This chapter includes the literature survey which covers the discussion of the work already done related to the proposed work.

Chapter 3: In this chapter, problem statement has been described and the work that is proposed is explained in brief.

Chapter 4: In this chapter, implementation and the results of MSE and PSNR using MATLAB tool is shown using snapshots.

Chapter 5: This chapter concludes the thesis and the future scope of the proposed work are discussed.

Chapter 2 Literature Review

In Image processing when one type of image is converted to another form by using different procedures, it may possible to degrade the quality of the output. There are many reasons behind the degradation of quality because while the process of noise removal, the image may get corrupt or blurred. So process the image inefficient way and maintain quality is crucial research problem for researchers. There are many techniques proposed by different researcher which use the different approach for image denoising and process it as per requirement of the condition.

Darwish *et al.* [1] introduced an adaptive threshold estimation procedure which uses DOP (Difference Operator), SFM (Spatial Frequency Measure) for image denoising which is more efficient than ROF filter. Threshold value calculated by using this concept improved the quality of the image by increasing PSNR for all types of noises.

Bawa and Sakshi [2] suggested the Modified Decision Based Unsymmetric Trimmed Median Filter is remove noise from images with good performance than other algorithms but it is very slow to be processed and edges are not that much clear. So use relaxed filter which reduce noise at its best level with higher speed and also preserve edges compared to other techniques. It uses DCT technique for image compression.

Huang *et al.* [3] focused on the nonparametric optimum threshold value by the variance between classes in a gray level image. It basically based on bi-level thresholding. But images are actually more complicated in real so it is not sufficient to handle it by using bi-level thresholding. In multilevel thresholding is used in which multiple thresholds are taken for segment images. In addition valley estimation was also used in it to determine the number of clusters. Here while processing image computation complexity is avoided for image with higher number of clusters.

Kaur and Garg [4] presented the study and comparison of gray scale images noise reduction techniques along with linear and nonlinear filters. This survey provides the best out of all algorithms with preserving for the decline noise from a grayscale image.

Shinde *et al.* [5] introduced the noise detection and removal techniques are applied on medical images like Cancer, Brain, MRI, X-Ray and various filtering techniques are applied to it to detect patterns of denoising. This has shown that which filter to use for greater efficiency depends on the type of noise and technique use for filtering.

Vishwakarma [6] discussed the different image enhancement techniques which clearly stated that modern Enhancement techniques like SSR & MSR give a much good performance but still have color rendition problem. Image enhancement is nowadays primary requirement in good pictures as images may degrade its quality due to lighting or another factor while capturing the image.

Zhang and Wu [7] introduced one hybrid technique which used Otsu's binary thresholding concept along with two-dimensional median filters to denoising the image more reliably and efficiently. To improve computation time packed binary format (PB) and source word accumulation (SWA) is used for denoising.

Om and Biswas [8] focused on the improvement method which calculates the threshold of wavelet and neighboring frame size for whole subband on the basis of its length. The result of the experiment shows the proposed improvement method is superior to the existing thresholding measure methods of the wavelet.

Zhu and Chan [9] studied the different approach for image denoising which uses L1 norm of mean curvature of the image. This model can keep corners and edges of objects and grey scale intensity contrasts of images. In addition to this model can also remove staircase effect even for smooth parts of images.

Sylvain and Froment [10] proposed a model of wavelet coefficient reconstruction using variation minimization algorithm. Inspired by the wavelet signal denoising method with small wavelet coefficient replaced by value minimizing to total variation artifact-free signal denoising. This proposed algorithm based on a sub-gradient combination on a linear space.

Aggarwal *et al.* [11] introduced the wavelet transform algorithm for signal denoising. They calculate Mean square error (MSE) and Signal to Noise Ratio (SNR) and compared them for both soft and hard thresholding which shows that soft thresholding gives better improvement in SNR than hard thresholding.

Karthikeyan and Chandrasekar [12] proposed a new method which used the hybrid model by combining fourth order PDE based anisotropic diffusion, bases shrink technique and SRAD filter. This new technique can produce good images by denoising images compared to traditional filters. In the field of Medical Science, Ultrasonic devices are used for diagnosis of diseases which may suffer due to speckle noise.

Trivedi and Shantaiya [13] applied an iterative phase retrieval algorithms. They can't recover the real period of the sign (picture) because of the nearness of clamor yet the recovered stage is a fractional recreation of the information picture alongside noise. This boisterous picture can be upgraded by applying filtering strategy by utilizing channels. In this place three filters are used to enhance the image they are Lucy Richardson filter, Wiener Filter and Inverse filter. Separately all the three channels prepared the picture for improvement and the yield of all the three are looked at for better reconstruction.

Qawasmi and Daqrouq [14] worked in the field of Medical Science by proposed a new technique for ECG signal Enhancement using wavelet transform. This method has better image quality than FIR filter and Donoho's wavelet thresholding coefficients.

Milanfar and Chatterjee [15] suggested patch-based wiener filter which performs patch redundancy. This approach did not require parameter tuning and authors analyzed the structure top to bottom for contrasting its relation with nonlocal means and remaining filtering techniques.

Sudha *et al.* [16] proposed a method for noise reduction in the image by combination if wavelet denoising technique with thresholding optimization functions. Along with wavelet denoising algorithm proposed algorithm is apply on the noise image and finally proposed algorithm is best in terms of PSNR and the preservation of edge information.

Shrivastava *et al.* [17] studied all types of noises (salt & pepper noise, Poisson noise, amplifier noise and speckle noise) and compare different types of filters like wiener filter, Inverse filter and lucy-Richardson filter. All types of filters are compared to different types of parameters and concluded that wiener filter and Lucy-Richardson filter performed well by denoising the images for most of the types of noises.

Cai *et al.* [18] proposed a new novel algorithm named singular value thresholding algorithm which approximates the matrix with minimum nuclear norm with some constraints. In this algorithm due to, soft thresholding is applied to the sparse matrix and no decreasing nature of rank of iteration; it is very useful for low-rank matrix problems.

Thivakaran and Chandrasekaran [19] introduced a new method for image restoration which was based on nonlinear Adaptive median filter. For the small neighborhood, it has higher efficiency but for high noise or large image it gives blurring effect in the image but compares to CWMF (center weighted median) it gives much good performance.

Xuea and Titterington [20] focused on two median based approaches for image thresholding: one is as per Otsu's method and other is as per Kittler and Illingworth's minimum error thresholding. By the combination of two approaches, it gave more robust performance than both original approaches.

Zhiyong *et al.* [21] proposed a denoising algorithm GA-ELM using the genetic algorithm in extreme machine learning algorithms. Firstly training the sample to prepare GA-ELM for noise detector then prepared GA-ELM to perceive noise pixels in the target objective image and in the end adaptive weight calculation is utilized to recoup the clamor pixels.

Chang *et al.* [22] proposed an adaptive, data-driven threshold technique. This technique used for picture denoising by means of wavelet soft-thresholding. The edge is determined in a Bayesian system and the earlier utilized on the wavelet coefficients is the generalized Gaussian distribution generally utilized as a part of picture preparing applications. The proposed edge is basic and shut structure, and it is versatile to each subband on the grounds that it relies on upon information driven assessments of the parameters.

Otsu [23] combined a nonparametric optimum threshold value by the variance between classes in a gray level image. It basically based on bi-level thresholding. But images are actually more complicated in real so it is not sufficient to handle it by using bi-level thresholding.

Donoho and Johnstone [24] described the new principle for spatially-adaptive estimation for selecting wavelength reconstruction. In this study, proposed a method for spatially adaptive in practically. Shrinking Empirical wavelet coefficients for works RiskShrink which mimics the performance for selecting wavelet reconstruction in oracle.

Rai *et al.* [25] studied the shrinkage of the wavelet in various shrinking methods in DWT in which these methods use often for suppressing AWGN where larger wavelength coefficient is attended by the threshold. Compression between filter efficiency also reviewed.

Iain and Bernard [26] suggested the empirical Bayes method for the purpose the threshold selection in wavelet shrinkage at level dependent. In the practice session, the estimation is quickly evaluated with the help of some software available. A general result of risk, overall bound on the risk of the technique is in subject to membership of undefined function in a range of Before class.

Alsaidi and Mohd [27] proposed the description of threshold selection methods which consider Ebays, level dependant cross-validation, universal, two-fold cross validation and sure. A simulation study to compare numerical performance using three various noise structures.

Motwani *et al.* [28] surveyed on image denoising techniques because the removing the noise from the original signals are very difficult and challenging problem. A discussion for some popular techniques and group them and algorithms overview and analysis.

Dengwen and Wengang [29] combined the improvement method in the NeighShrink algorithm which is image denoising technique based on the Decimated wavelet transform. Improved methods determine the optimal threshold and nearest window size for each subband with Stein’s unbiased risk estimate. The suggested technique is also extended of DT-CWT algorithm and experiment achieve they better results with DT-CWT.

Jana and Sinha [30] studied the noise removal technique from an image using the discrete wavelet transform. The threshold is the heart of denoising and the application of perfect edge can remove the noise. Some famous thresholds are SureShrink, VishuShrink, etc. these popular thresholds are discussed in the work.

Foster and Stine [31] proposed an adaptive shrinkage estimator for regression problems lie wavelet estimation. Proposed estimator, PolyShrink fluctuates the measure of shrinkage to match the estimation errand. PolyShrink limits hold for any sample size and point wise which shows it produce a fitted model whose dissimilarity exist in a consistent element.

Fadek and Nakaonechnyy [32] presented intra-scale dependencies of the wavelet to enhance the noise reduction it gives the information of the neighboring wavelet that creates cluster inside. The extensive experiment result gives the strength of proposed technique.

Sabahaldin and Gorashi [33] proposed a new image denoising algorithm based on neighborhood thresholding function. In this magnitude of wavelet coefficient is consider it is noisy or not. The proposed algorithm is adapt the window size and threshold value according to estimated noise value. Experimentally proven that proposed algorithm remove noise efficiently with little processing time.

Kaur *et al.* [34] suggested an adaptive threshold estimation technique for noise reduction in the image with generalized Gaussian distribution (GGD) in the wavelet domain. Proposed method called as NormalShrink practically more adaptive and efficient due to threshold depends on subband data. The proposed method gives the significant result over OracleShrink and SureShrink pre-existing methods.

Unser *et al.* [35] studied denoising of orthonormal wavelet image which describes the orthogonal wavelet thresholding algorithm and shows its near optimal performance. In this performance, it shows both CPU requirement and quality by comparing with three state-of-the-art nonredundant denoising techniques.

Levent and Selesnick [36] conducted the dependency between child coefficient and their parent. To achieve this non-gaussian bivariate distribution are proposed and drive their functions using Bayesian estimation theory. The new function does not suppose to be independent of wavelet coefficient. It will be shown the three image denoising examples in the sequence of performance.

Chen *et al.* [37] proposed a NeighShrink method of one wavelet image threshold and this is valid due to large wavelet coefficient probably have large neighbors wavelet coefficient. An experimental result tell the comparison between proposed method and the existing methods and shows the better result as compare to VishuShrink and SureShrink.

Chapter 3 Problem Statement

In wavelet denoising, the thresholding calculation is normally utilized as a part of orthogonal decomposition i.e. wavelet packet transform and multi-determination examination. Wavelet thresholding confronts a few issues in its application, for instance, the choice of soft or hard threshold, level-dependent or fixed threshold.

Besides the influence of thresholding, the impact of wavelets is additionally a critical component. In many applications, the wavelet change utilizes a couple of non-zero coefficients to depict a function or signal. The presence of small coefficients is more due to noise which needs to be threshold without influencing the noteworthy elements of the picture. Thresholding the image and reconstructing it may lead to poor image quality.

As in wavelet transform poor directionality and poor geometrical oriented decomposition is achieved in multiple directions. So there is a need to set the threshold limits depending on the variables like length of the image and input vector X with a given threshold T.

The aim of this thesis is to improved an algorithm with spatially adaptive type of thresholding in wavelet transform technique which performs soft thresholding on diagonal axis along XY axis. And last but not the least to provide a new method to calculate threshold for the adaptive algorithm.

4.1 Proposed Algorithm

This chapter consist proposed algorithm’s steps. It has given the different steps which are required to implement the proposed algorithm as shown as Fig. 4.1.

1. Load the image
2. Add Generalized Gaussian Distribution Noise
3. Apply Wavelet Decomposition
4. Find the median value, sigma and beta for the wavelet transformed image
5. Calculate the threshold value for SAWT algorithm.
6. Apply Soft Thresholding to replace noisy coefficients by zero to suppress noise using value from step 4.
7. Normalize the noisy image coefficients horizontally, vertically and diagonally using 2d integer wavelet transform.
8. Reconstruct the image using threshold wavelet coefficients.
9. Calculate MSE and PSNR.

All the above steps mentioned represented in form of a flow diagram 4.1 as follows

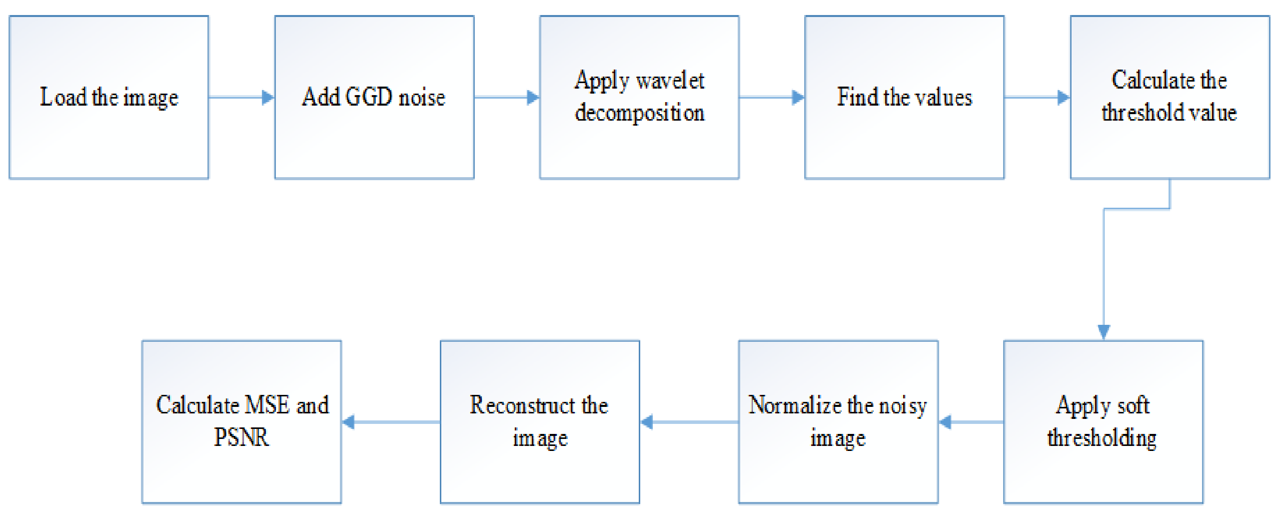

Fig. 4.1: Flow diagram of Proposed Method

Image denoising is unique method of removal of noise while holding however much as could be expected important information. It is the method of producing a good estimate of the original image from noisy observations.

There are two basic methods to image denoising, name as

- **Spatial Filtering method**
  It is an attempt to remove the noise by controlling the image in the spatial domain itself.
- **Transform filtering method**
  It utilizing some changes to control the image in change domain.

In transform domain, wavelets give a better execution in picture denoising due than its properties, for example, multi-resolution structure, energy compaction and sparsity. Along these lines, the center was moved from the spatial and Fourier area to the wavelet transform domain.

In images with Gaussian noise, thresholding is considered to be the perfect solution. The hypothetical formalization of filtering additive Gaussian noise through thresholding wavelet coefficients was proposed by Johnstone and Donoho.

A wavelet coefficient is checked with concerning a given threshold value and its value is set to zero if its extent is not exactly the edge; else, it is spared or changed relying upon the thresholding guideline. The edge value goes about as a worth which settles on the immaterial coefficients known as noise, and the vital coefficients containing the picture signal. Thresholding is more successful for signals with near-sparse or sparse representations were just a little subset of the coefficients speaks to all or the greater part of the picture signal. Thresholding basically makes a locale around zero where the coefficients are viewed as irrelevant. The threshold coefficients are used without quantizations which are out of the region.

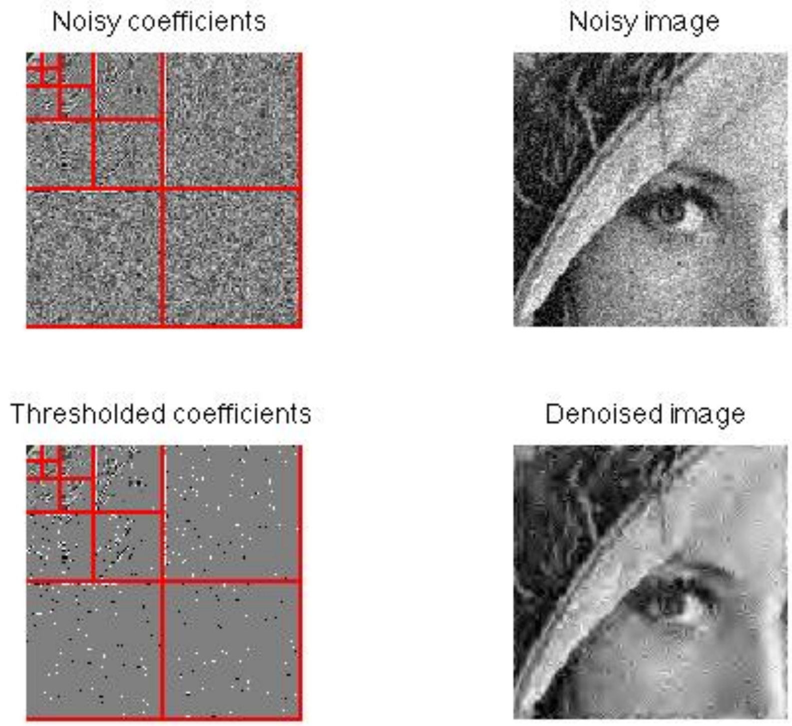

Fig. 4.2: Noisy and Denoisy image

In wavelet transform, the small coefficients are more probable because of the presence of unwanted distortion known as noise and large coefficients are more probable because of imperative component of the picture.

There is always requirement of processing of the image pixels which does not induce the smaller coefficients which comes automatically when the image is reconstructed or compressed or the resolution is affected in any manner. These small coefficients can be limit without influencing the noteworthy components of the picture.

Let the image be $\{f_{ij}\}$ and $\{E_{ij}\}$ is the additive Gaussian noise.
Now,

$$g_{ij} = f_{ij} + E_{ij} \tag{17}$$

where i, j= 1, 2, ….R and R is power of 2.

To minimize the MSE and to increase PSNR, we have to remove selected noise coefficients i.e. to remove E_{ij} from g_{ij}.

Let $\mathbf{E} = \{E_{ij}\}_{ij}$, $\mathbf{f} = \{f_{ij}\}_{ij}$ and $\mathbf{g} = \{g_{ij}\}_{ij}$ are the matrix representations of the image to be denoised. Now, Let Y = Wg is a matrix of wavelet coefficients of g, where W is a 2D orthogonal wavelet transform. On the other hand, the sub bands of the transform are labeled in figure below.

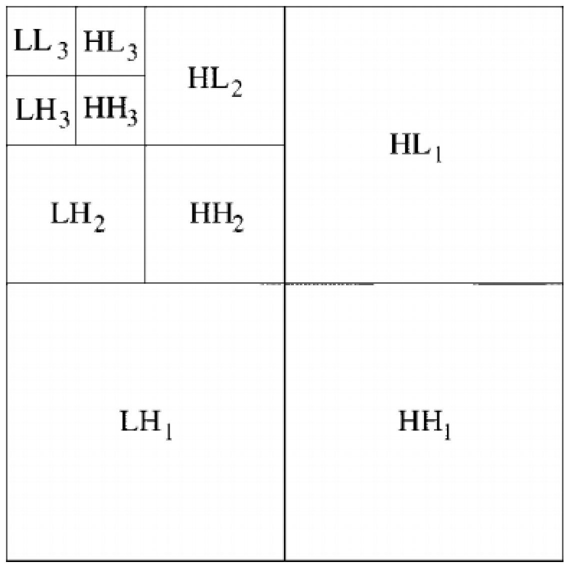

Fig. 4.3: Subbands of 2-Dimentional orthogonal Wavelet transform

The sub bands HH_p, HL_p, LH_p, p = 1, 2, ….., Q are known as the details, where p is the scale, with Q being the largest scale in the decomposition of the image.
The wavelet thresholding[9] based method checks for each coefficient Y_{ij} of the pixel from the sub bands using threshold function.

The two thresholding methods used are: Soft Thresholding and the Hard Thresholding.

- **Hard Thresholding**

  It function is shown as follows:

$$a_m(x) = \begin{cases} 0 & if \quad |x| < T \\ 1 & if \quad |x| \geq T \end{cases} \tag{18}$$

Now, the estimator with hard thresholding function:

$$\tilde{F} = \sum_{m=0}^{N-1} \rho_T(X_B[m]) g_m \quad \text{with} \quad \rho_T(x) = a_m(x) * x = \begin{cases} 0 & if \quad |x| < T \\ x & if \quad |x| \geq T \end{cases} \tag{19}$$

➢ **Soft Thresholding**

This function is implemented by:

$$0 \leq a_m(x) = \max(1 - \frac{T}{|x|}, 0) \leq 1 \tag{20}$$

with the thresholding function ρ_T replaced by a soft thresholding function.

$$\rho_T(x) = \begin{cases} x + T & if \quad x \leq -T \\ x - T & if \quad x \geq T \\ 0 & if \quad |x| \leq T \end{cases} \tag{21}$$

Out of both, Soft thresholding is more efficient as compared to the other to minimise the risk of thresholding in order to reduce the MSE value.

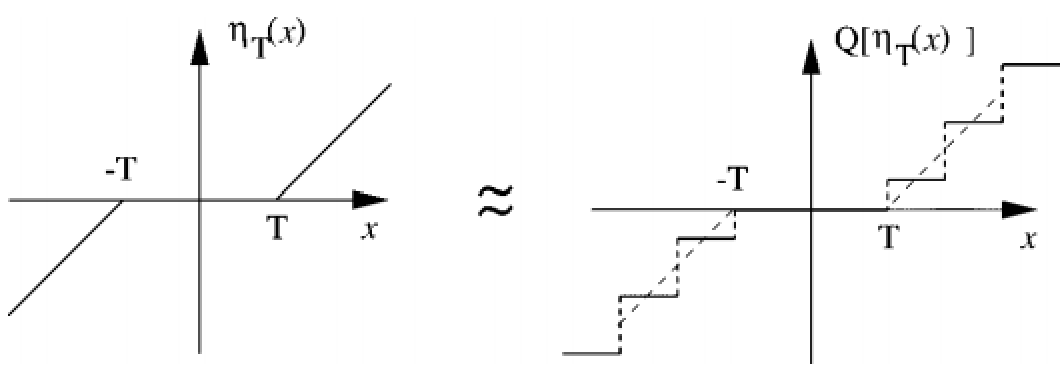

Fig. 4.4: Thresholding function

The hard thresholding expels the clamor in the range where the first signal f is customary. Contrasted and hard thresholding, the extent of coefficients with delicate thresholding is somewhat littler. The soft thresholding estimation weakens the commotion influence at the discontinuities, yet it likewise decreases the greatness of estimation.

The size of the image is calculated and a horizontal and a vertical soft thresholding is carried out. This dual axis approach helps the Spatially Adaptive Wavelet Transform (SAWT) algorithm to get a prior and smoother estimation of the noise present in the image.

The Generalized Gaussian Difference (GGD) parameters sigma and beta are calculated to estimate the thresholding value. For this noise variance $sigma^2$ [17] is detected firstly, which is measured from subband HH_1 by robust median estimator.

$$\hat{\sigma} = \frac{Median(|Y_{ij}|)}{0.6745}, \quad Y_{ij} \in subband\ HH_1 \tag{22}$$

When n x n is the size of subband under working,

$$\hat{T}_B(\hat{\sigma}_X) = \frac{\hat{\sigma}^2}{\hat{\sigma}_X} \tag{23}$$

where

$$\hat{\sigma}_X = \sqrt{\max(\hat{\sigma}_Y^2 - \hat{\sigma}^2,\ 0)} \tag{24}$$

Using the threshold value T_B, horizontal and vertical directions are processed as compared to the previous work where only diagonal thresholding was implemented.

4.2 Results

In order to implement the proposed algorithm; design and implementation is done in MATLAB using image processing toolbox. In order to do cross validation the proposed algorithm is compared with the existing algorithm and also using the performance calculator name as MSE and PSNR. Table 4.1 is showing the various images which are used in this research work. Images are given along with their format and size.

Table 4.1: Description of Images Used

Image no.	Image name	Size	Format
1	Lena_gray_512	257 KB	JPG
2	Mandril_gray	380 KB	JPG
3	Cameraman.bmp	546 KB	PNG
4	Woman_blonde	214 KB	JPG
5	Woman_darkhair	850 KB	PNG
6	Livingroom	645 KB	JPG

Fig. 4.5 has shown the input image which is used algorithm.

Fig. 4.5: Input image of Lena

Fig.4.6 show the noisy image of Lena(Left) and shown the denoisy image of Lena(Right).

Fig. 4.6: Noisy Image of Lena (Left) and Denoisy Image of Lena (Right)

Table 4.2 and Fig. 4.7 are showing the comparative analysis of the Mean square error (MSE). As MSE need to minimize; so our goal is to reduce them MSE as much as possible. Table 4.2 and Figure 4.7 are clearly shown that MSE is less in our case therefore proposed algorithm is providing better results.

Table 4.2 Mean Square Error

Image	Previous Technique Result	Proposed Technique Result
Lena_gray_512	67.6775	59.9729
Mandril_gray	131.6876	117.5134
Cameraman.bmp	66.1066	54.9739
Woman_blonde	107.6470	91.6915
Woman_darkhair	30.4885	27.1262
Livingroom	123.4282	104.4979

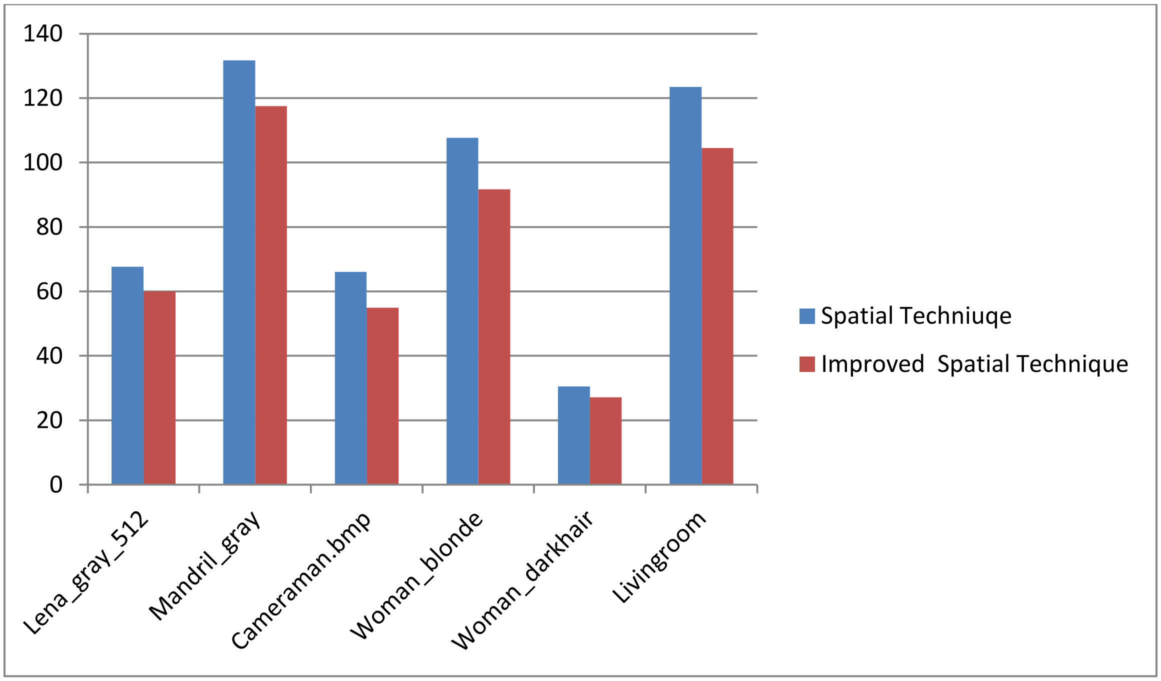

Fig. 4.7: Comparison between Spatial and Improved Spatial Technique using MSE

Table 4.3 and Figure 4.8 are showing the comparative analysis of the Peak Signal to Noise Ratio (PSNR). As PSNR need to be maximized; so our goal is to increase PSNR as much as possible. Table 4.3 and Figure 4.8 is clearly shown that PSNR is maximum in our case therefore proposed algorithm is providing better results.

Table 4.3 Peak Signal to Noise Ratio

Image	Previous Technique Result	Proposed Technique Result
Lena_gray_512	29.8264	30.3512
Mandril_gray	26.9354	27.4299
Cameraman.bmp	29.9284	30.7292
Woman_blonde	27.8108	28.5075
Woman_darkhair	33.2894	33.7969
Livingroom	27.2167	27.9397

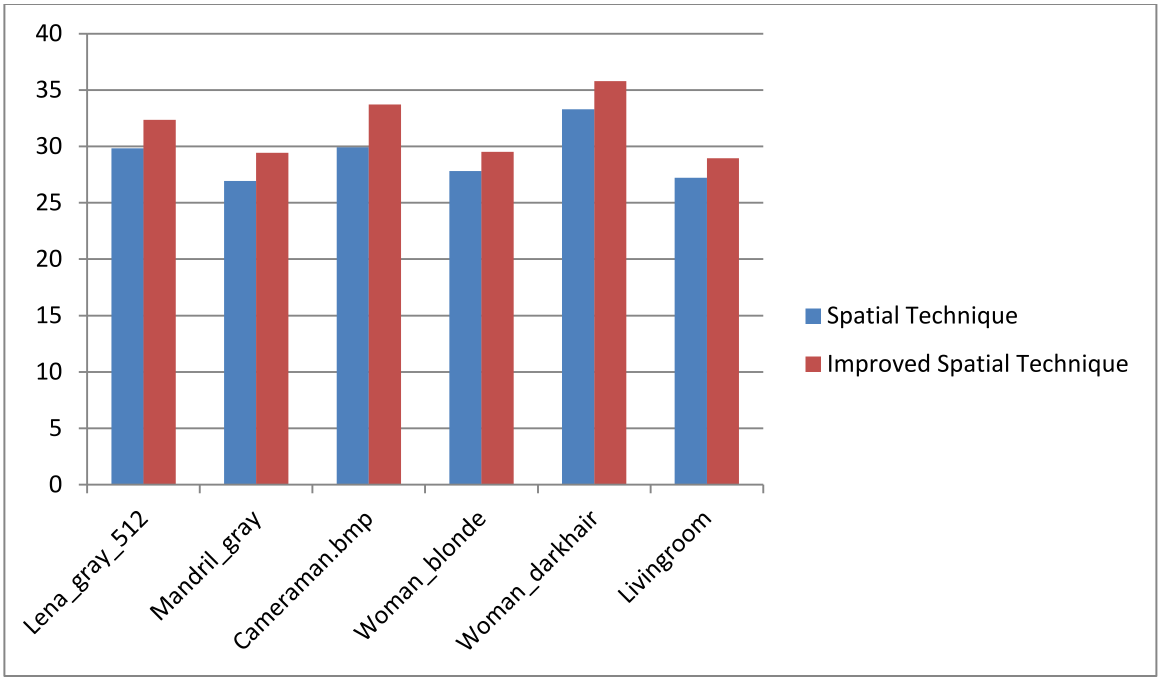

Fig. 4.8: Comparison between Spatial and Improved Spatial Technique using PSNR

Chapter 5 Conclusion and Future Scope

In this thesis, Image restoration is the process of eliminating or reducing noise from a degraded image with an objective to recover, the original image. Noise is a quality degradation factor that is measured as unwanted/unrelated information present in the image. The proposed algorithm removes impulse noise at high noise density and gives better Peak Signal-to-Noise Ratio (PSNR) and Mean Square Error (MSE).

The wavelet denoising techniques are typically acknowledged by orthogonal decomposition. The most generally utilized orthogonal decompositions are wavelet packet transform and multi-resolution analysis. The impact of wavelet decomposition algorithms, soft or hard thresholding and level-dependent or fixed thresholds are analyzed and studied. For a various application, the ideal wavelet thresholding strategy which is proposed attains lower mean square error (MSE). This segment concentrates on the estimation of the GGD parameters, which thusly yields an information-driven appraisal of that is versatile to various sub-band attributes.

The wavelet transform is to utilize a couple of huge magnitude coefficients to speak to an image signal. The choice of the wavelet is another imperative element that necessities thought, which in out implementation is the HH. The properties, for instance, degree and regularity, of sign ought to be concentrated on while picking ideal wavelet or before selecting the type of thresholding or its limits that has coordinating components, for example, regularity and size of support.

Overall the proposed algorithm carries out a specific way to select the threshold level to noise levels assessed from the sub-band by the solid median estimator.

The future scope of this approach may cover the smoothening of the artifacts in the resultant outputs. Another perspective can be handled and implemented for the online or remote denoising at the real time for video and motion graphic

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