A BASIC OVERVIEW ON IMAGE DENOISING TECHNIQUES

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***Abstract: -** In present era visual information is very significant. Since, visual information transmitted in the form of digital images is becoming a most important technique of communication. Therefore, Image Processing plays a very vital role in progressive accomplishments wherever the images are used. Digital image processing deals with the digital images such as computerized images, MR images, etc. and it is very essential that these images are in precise shape. However during transmission of images, they often find corrupted with noise. To overcome this issue, various noise removal methods have been developed for eliminating noise and preserving edge details in the image. In that case every method has its own benefits and drawbacks. The initiative behind these methods is to acquire superior results in terms of quality and in elimination of different noises. This paper presents a review of some significant work in the domain of image denoising.*

Keywords**: - **Image denoising, Gaussian noise, Salt and pepper noise, impulse noise, spatial filters, Wavelet transform.

I. INTRODUCTION

Digital images play a very significant role in applications like television, MR Imaging, Computed tomography, geographical information system and astronomy. Collections of information gathered by image sensors and other devices are normally polluted by noise. Moreover, noise may occur owing to transmission errors and compression. Hence, denoising is often desirable and is first step to be performed prior to image data is investigated and processed. With recent advances in image technology, image denoising has found renewed interest for researchers. Image denoising is one of the elementary challenges in the domain of image processing, where the fundamental objective is to estimate the original image by curbing noise from a noise-polluted version of the image. Image noise may be caused by various intrinsic (sensors, image capturing devices etc.) and extrinsic (environment) surroundings which are frequently not feasible to evade in practical circumstances. Therefore, image denoising plays a significant role in a broad range of applications such as image restoration, visual, tracking, image registration, image segmentation, and image classification, where acquiring the original image content is vital for reliable performance. The objective of de-noising is to eliminate the noise at the same time, retaining maximum possible significant signal information of an image. Various types of images accede to different kinds of noise and different noise representations are used to present different noise types. Denoising process tends to be issue specific and depends upon the type of image and noise model [1]. Noise is generally modeled as Gaussian noise (Normal), Uniform noise and Impulse noise (salt and pepper noise) in [2, 3]. The impulse noise is of two kinds, Fixed valued and random valued. The fixed valued impulse noise is too called as salt and pepper noise which can have value either 0 or 255. Here 0 denotes absolute black and 255 denotes absolute white on gray scale image. The random valued impulse noise can have any value from 0 to 255; therefore, its elimination is very significant and complex. Image de-noising is a vital pre-processing phase for image analysis. Image denoising process yet remains an imperative challenge for researchers since; denoising process eliminates the noise however, introduces artifacts and also causes blurring. In this paper various methods of image noise reduction techniques are discussed. This paper is presented in five sections including the introduction. In section II noise model for different types of noise is described. Section III presents the brief idea regarding the evolution of image denoising methods. Section IV describes the classification of different image denoising approaches. Lastly, section V gives the conclusion of the work.

1.1 NOISE SOURCES: - Noise may introduce in the image during image acquisition and image transmission. There may be various causes for the introduction of noise in the image. The number of pixels corrupted in the image decides the quantification of the noise. The main sources of noise in the digital images are: - (i) Environmental circumstances may influence the imaging sensor. (ii) Low light and sensor temperature may set up noise in the image. (iii) Dust particles present in the scanner may bring in noise in the digital image. (iv) Interference in transmission channel [4]

II. NOISE MODELS

Noise may be present in image in the following two forms:-

(i) Additive form

(ii) Multiplicative form

(i) Additive Noise Model: - Noise signal that is additive in nature gets added to the original signal to produce a corrupted noisy signal and follows the subsequent model:

w(x, y) = s(x, y) + n(x, y) ……………………..(1)

The Gaussian noise is a kind of additive noise it uniformly distributes itself over the signal. This kind of noise has a Gaussian distribution [12].

(ii) Multiplicative Noise Model: - In this model, noise signal gets multiplied to the original signal. The multiplicative noise model follows the subsequent rule:

w(x, y) = s(x, y) × n(x, y) …………………(2)

Where, s(x, y) is the original image intensity and n(x, y) signifies the noise introduced to compose the corrupted signal w(x, y) at (x, y) pixel position [5].

2.1 TYPES OF NOISES

The noise is distinguished through its pattern and by means of its probabilistic characteristics. There is an ample diversity of kinds of noise. Whilst we concentrate only on the most significant types, namely; Gaussian noise, salt and pepper noise, poison noise, impulse noise, speckle noise [6].

a) Gaussian Noise: - Gaussian noise is statistical noise that has its probability density function (PDF) equal to that of the normal distribution, which is as well acknowledged as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed. A special case is white Gaussian noise, in which the values at any pair of times are equally distributed and statistically independent (un co-related). In applications, Gaussian noise is most frequently used as additive white noise to acquiesce additive white Gaussian noise.

b) Salt and Pepper Noise: - Salt and pepper noise is a kind of noise normally observed on images. It signifies itself as randomly arising white and black pixels. An efficient noise elimination technique for this kind of noise involves the usage of a median filter, morphological filter or a contra harmonic mean filter. Salt and pepper noise sneaks into images in circumstances where fast transients, such as faulty switching occur.

c) Poison Noise: - Poisson noise is induced through the nonlinear response of the image detectors and recorders. This kind of noise is image data reliant. This term occurs since detection and recording processes involve arbitrary electron emission having a Poisson distribution with a mean response value. Since the mean and variance of a Poisson distribution are identical, the image dependent term has a standard deviation if it is assumed that the noise has a unity variance.

d) Impulse Noise: - Impulse noise is a class of (acoustic) noise which comprises unwanted, approximately instantaneous (impulse-like) sharp sounds (like, clicks and pops). Noises of this kind are generally caused by electromagnetic interference, scratches on the recording disks, and ill synchronization in digital recording and communication. Impulse noise corruption is most familiar in digital images. Impulse noise is always independent and uncorrelated to the image pixels and is randomly distributed over the image. Hence unlike Gaussian noise, for an impulse noise corrupted image all the image pixels are not noisy, a number of image pixels will be noisy and the rest of pixels will be noise free. There are different types of impulse noise namely salt and pepper type of noise and random valued impulse noise. In salt and pepper type of noise the noisy pixels takes either salt value (gray level = 225) or pepper value (gray level = 0) and it appears as black and white spots on the images. If p is the total noise density then salt noise and pepper noise will have a noise density of p/2.This can be mathematically represented in eq. (3).

$$y_{ij} = \begin{cases} 0 \; or \; 255 \;\; with \;\; probability \; p \\ xij \;\; with \;\; probability \; 1-p \end{cases}$$ ---------------- (3)

Where y_{ij} denotes the noisy image pixel, p is the total noise density of impulse noise and xij is the uncorrupted image pixel. At times the salt noise and pepper noise may have different noise densities and thus the total noise density will be $p = p_1+p_2$.

In case of random valued impulse noise, noise can take any gray level value between 0 and 225. In this case as well noise is randomly distributed over the complete image and probability of incidence of any gray level value as noise will be same.

We can mathematically represent random valued impulse noise as in equation (4).

$$y_{ij} = \begin{cases} nij \; with \; probability \; p \\ xij \; with \; probability \; 1-p \end{cases}$$ ------------------ (4)

Where nij is the gray level value of the noisy pixel.

e) Speckle Noise: - Speckle is a complicated event, which degrades image quality with a backscattered wave look which originates from various microscopic diffused reflections that passing through internal organs and makes it more complicated for the observer to differentiate fine detail of the images in diagnostic tests. This kind of noise arises in nearly all coherent systems like SAR images, Ultrasound images etc. The cause of this noise is random interference among the coherent returns. The speckle noise follows a gamma distribution [7]. Hence, the cause of this noise is arbitrary intervention among the rational returns. Hence, denoising the noise from a noisy image has become the major step in medical image processing. For the quality and edge preservation of images we have taken different denoising techniques into consideration.

III. EVOLUATION OF IMAGE DENOISING TECHNIQUES

Primary complexity in image processing is to curb the noise in degraded image. Initially a spatial domain approach has been implemented. One of the major benefits of this filter domain approach is that this approach is fast. However, the limitation of this approach is it was incapable to conserve edges, which are recognized as discontinuities in the image, alternatively wavelet domain technique having a immense benefit of conserving edges, was introduced later on. This approach becomes more popular for denoising of images. Various algorithm for denoising in wavelet domain were implemented subsequently it was observed that substantial enhancements in perceptual quality could be achieved by translation invariant algorithms based on thresholding of an Undecimated Wavelet Transform. Multi wavelets were also utilized to attain identical outcomes. To minimize the artifacts these thresholding approaches were applied to non orthogonal wavelet coefficients [8].

IV. CLASSIFICATION OF IMAGE DENOISING TECHNIQUES

Figure1 shows the detailed classification of image denoising techniques

Basically there are two types of approaches for image denoising:-

(i) Spatial filtering approach

(ii) Transform domain filtering approach.

4.1 Linear Filters

Linear filters also known as average filter are normally of two types: mean filter and wiener filter. Linear filters also liable to blur sharp edges, corrupt lines and other fine image information, and perform poorly in the existence of signal-dependent noise.

a) Mean Filter: - Mean filter is a simple, intuitive and easy to implement approach of smoothing images. Mean filter is a straightforward sliding window spatial filter that replaces the centre value of the window with the average (mean) values of its all adjacent pixels values together with itself. This has the consequence of removing pixel values which are deceiving of their neighboring. The two major difficulties with mean filtering are:-

(i) A single pixel with a very deceiving value can considerably affect the mean value of all the pixels in its vicinity.

(ii) When the filter neighborhood overlaps an edge, the filter will interrupt new values for pixels on the edge and so will blur that edge. This may be a setback if sharp edges are needed in the output. Mean filter is employed with the convolution masks, which gives the result that is weighted sum of values of a pixel and its neighbors. The kernel is square; often 3×3 mask is used.

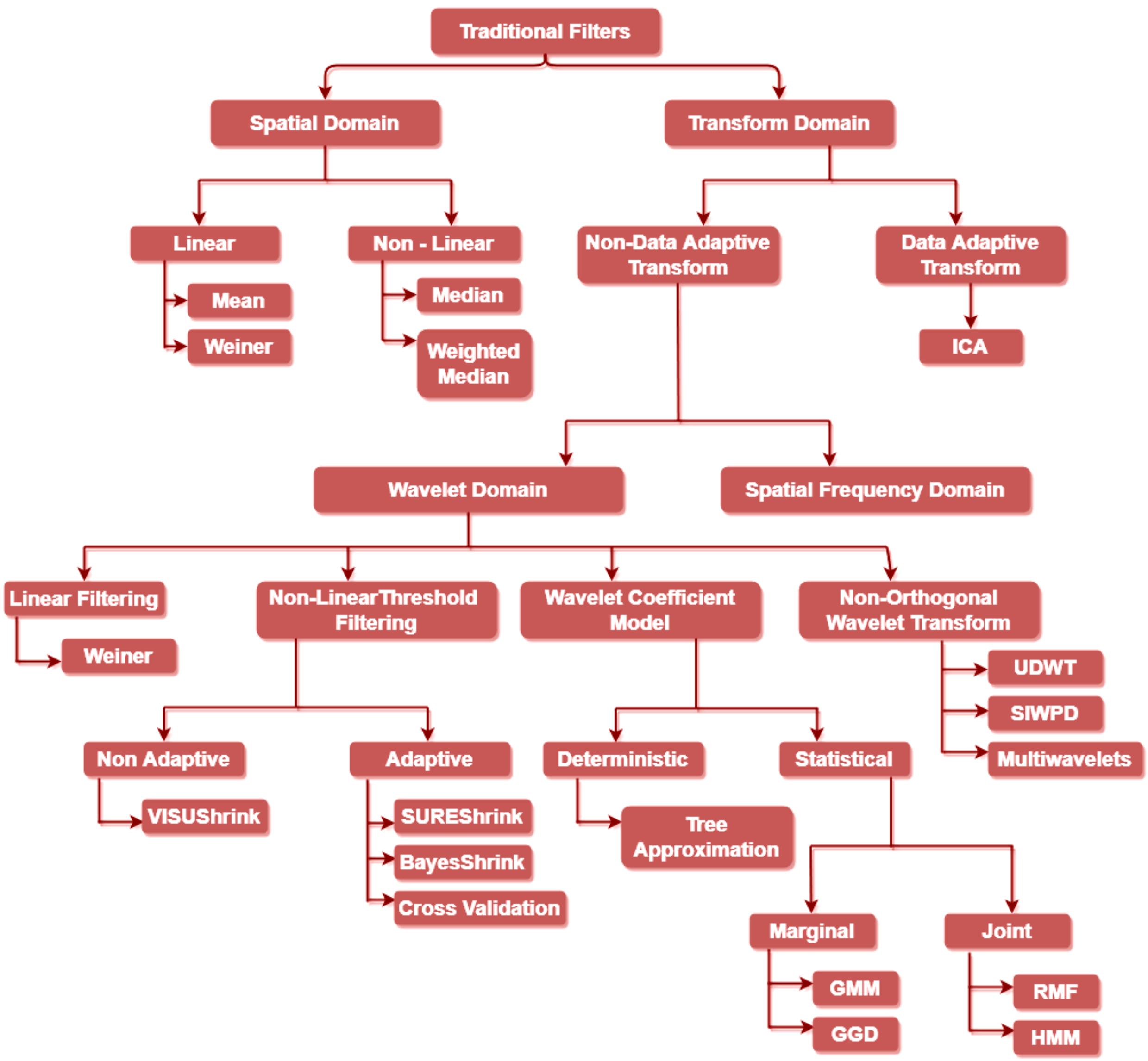

Figure1. Classification of image denoising techniques

b) Wiener filter: - The wiener filtering approach needs the information regarding the spectra of the noise and the original signal and it functions better only if the original signal is smooth. Wiener method applies spatial smoothing and its model difficulty control corresponds to selecting the window size [10]. Wiener filtering is able to achieve significant noise elimination when the variance of noise is low; they cause blurring and smoothening of the sharp edges of the image [11]. To overcome the limitations of spatial domain filtering Donoho and Johnstone suggested wavelet based denoising method.

4.2 Non-Linear Filters

Spatial filters utilize a low pass filtering on sets of pixels with a postulation that noise occupies the higher frequency area of the spectrum. Normally spatial filters remove noise to a significant extent however at the cost of blurring images which in turn makes the edges in pictures invisible. Recently a variety of non linear filters have been developed. The simplest nonlinear filter is the median filter.

a) Median Filter

Median filter is one of the most important filters to suppress random valued impulse noise. It is a non-linear type filter. In this filter the value of corrupted pixel in noisy image is replaced by median value of corresponding window. Median value is the value in the middle position of any sorted sequence [9]. Consider that the pixel values in neighbor-hood are taken into a sequence and it becomes after sorting in descending order or in ascending order. Median filter is also called the order specific filter since it is based on statistics derived from ordering the elements of a set rather than taking the means. This filter is popular for reducing noise without blurring edges of the image [8]. It is mainly useful to shrink salt and pepper noise and speckle noise as well. Its edge preserving character makes it usable in cases where edge blurring is objectionable. The median filtered image g(x, y) may be obtained from the median pixel values in a surrounding of (x, y) in the input image f(x, y), is given by equation (5)

$$MdF(x_i) = Median(\|x_i\|^2) \text{ ---------------- } (5)$$

Where, i = 1 .... N

b) Spatial Median Filter (SMF)

The spatial median filter is also noise removal filter where the spatial median is computed by calculating the spatial depth between a point and a set of point. In this filter after computing the spatial depth of every point lying inside the filtering mask, this information is used to make a decision whether the central pixel of window is corrupted or not, if central pixel is uncorrupted then it will not be changed. Next, the spatial depth of each pixel within the mask is computed and then sorted these spatial depths in descending order .The point with highest spatial depth signify the spatial median of the set. If central pixel is corrupted with noise then it is restored by computed spatial median [10].The spatial depth is defined by equation (6)

$$S_d(X, x) = \left(1 - \frac{1}{N-1}\left|\sum_{i=1}^{N} \frac{X - x_i}{|X - x_i|}\right|\right) \text{-------------- } (6)$$

c) Weighted Median Filter (WMF)

The centre weighted median filter is an expansion of the weighted median filter. The previously designed weighted median filter offers more weight to some values inside the window while centre weighted median filter gives more weight to the central value of a widow hence easier to design and implement than other weighted median.

4.3 Spatial Filtering

It is a conventional approach to eliminate noise from image. Spatial filters are direct and high speed processing tools of images. Spatial domain filters are further categorized as linear filters and non-linear filters.

4.4 Transform Domain

Classification of Transform domain filtering approach depends upon choice of basis function. The basis functions can be further categorized as Non-data adaptive and data adaptive. Principally we will discuss Non-data adaptive transforms as they are more accepted [12].

4.4.1 Non-Data Adaptive Transform

a) Spatial-Frequency Filtering

Spatial frequency domain denoising approach is a category of Transform Domain, filtering where low pass filters (LPF.) is used with Fast Fourier Transform (FFT). Here denoising is accomplished by designing a cut-off frequency. But these approaches are time consuming and may generate artificial frequencies in processed image.

b) Wavelet Domain: **-** Wavelet approach for noise elimination has been effectively exploited various researchers in the past few decades. It has been revealed that the application of wavelets productively eliminates noise while preserving the signal information, despite of its frequency content [13].

Wavelet transformation is a multi resolution demonstration of signal and image in two dependant domains, which decompose the signal and image into multi scale resolution. The localization of the wavelet basis functions in both time and frequency domain guides to multi resolution study and successful filter designs for precise applications. Wavelet decomposition conserved and represented the sharp transition in images, which results in more precise edge detection in images. These characteristics of the wavelet transform make it very useful for denoising. Wavelet transform is achieving popularity in the domain of biomedical image denoising owing to its sparsity and multi resolution characteristics. In recent years, the multi resolution wavelet denoising techniques have used in biomedical image. Various wavelets such as Haar, Daubechies, Symlet, Discrete Meyer Coiflets and Biorthogonal have been implemented for denoising. The Daubechies wavelet transforms are stated in the same means as the Haar wavelet transform by computing the running averages and differences through scalar products with scaling signals and wavelets the only difference between them consists in how these scaling signals and wavelets are stated[14]. Daubechies wavelets employ overlapping windows, so the high frequency coefficient spectrum reflects all high frequency changes. Therefore Daubechies wavelets are helpful in noise removal of image processing [15].

The Fast Wavelet Transform is a mathematical algorithm designed to turn a waveform or signal in the time domain into a sequence of coefficients based on an orthogonal basis of small finite waves, or wavelets. The transform can be simply expanded to multidimensional signals, like as images, where the time domain is substituted with the space domain. It has as theoretical foundation the device of a finitely generated, orthogonal multi resolution analysis (MRA). Transform coding is an extensively used method of compressing image information. In a transform-based compression system two dimensional (2-D) images are transformed from the spatial domain to the frequency domain. A successful transform will focus useful information into a few of the low-frequency transform coefficients. Wavelet-based image processing methods are usually realized by memory-intensive algorithms with higher execution time than other transforms. In the usual DWT implementation [16], the image decomposition is computed by a convolution filtering method and hence its complexity increases as the filter length increases. moreover, in the regular DWT computation, the image is transformed at each decomposition level first row by row and then column by column, and therefore it must be kept totally in memory. Fast wavelet transform algorithms have been proposed in order to reduce both memory obligations and complexity. This approach boosts flexibility while applying wavelet transform and appreciably reduces the memory necessities. In 1988, Mallat introduced a fast wavelet decomposition and reconstruction algorithm [Mal89]. The Mallat algorithm for discrete wavelet transform (DWT) is, in fact, a standard scheme in the signal processing community, known as two channel sub band coder using conjugate quadrature filters or quadrature mirror filters (QMFs). Wavelet domain process is again divded in to two types i.e. linear and non-linear techniques.

(i) Linear Filters
Normally used linear filter in this class is Wiener filter. Wiener filter gives most useful outcomes in the wavelet domain. Wiener filtering is employed where data corruption can be modeled as a Gaussian process and accuracy measure is mean square error (MSE). But wiener filtering results in filtered image which is visually more disturbing

(ii) Non-Linear threshold filtering

Non-Linear threshold filtering is the most examined domain in denoising applying wavelet transform. It essentially employs the characteristic of wavelet transform and the information that wavelet transform maps noise in signal domain to that of noise in transform domain. Hence while signal energy turn into more concentrated into fewer coefficients in transform domain noise energy does not. The process where small coefficients are eliminated leaving other coefficients unharmed is known as Hard Thresholding. Though this approach creates spurious blips called as artifacts. To conquer these demerits soft thresholding was implemented where coefficients above the threshold are shrunk by the absolute value of threshold itself.

(a) Non-Adaptive Thresholds

Non-Adaptive thresholds normally used are VISUShrink. When the number of pixels attains infinity it demonstrates best performance in terms of MSE. VISU Shrink usually gives smoothed images.

(b) Adaptive Thresholds

Adaptive Threshold approach includes URE Shrink, VisuShrink and Bayes Shrink methods. The Performance of SURE Shrink is better in comparison to the VISU Shrink since SURE Shrink employs a combination of the universal threshold and the SURE [Stein's Unbiased Risk Estimator] threshold. When noise levels are higher than signal magnitudes the postulation that one can differentiate noise from the signal exclusively based on coefficient magnitudes is breached. Bayes-Shrink do better than SURE-Shrink most of the times. Bayes-Shrink reduces the Bayes' Risk Estimator principle assuming Generalized Gaussian prior and hence acquiescing data adaptive threshold

(iii) Non-Orthogonal Wavelet Transform

Non-orthogonal Wavelet Transforms includes Shift Invariant Wavelet Packet Decomposition (SIWPD) where numbers of fundamental functions are attained. Then by applying Minimum Description length principle the most excellent basis function is found out which give up smallest code length for given data .Then thresholding was applied to denoise the data. In addition to these Multi wavelets are discovered which further enhances the performance but at the same time increases the computational complexity [17].

(iv) Wavelet Coefficient Model

This approach makes use of the multi resolution characteristics of Wavelet Transform. The modeling of the wavelet coefficients can either be deterministic or statistical. This approach gives excellent output but it is computationally more complex and it is costly also. [18].

a) Deterministic

The Deterministic approach of modeling includes forming tree structure of wavelet coefficients. Here each level in the tree is representing each scale of transformation and every node representing wavelet coefficients.

b) Statistical Modeling of Wavelet Coefficients

This approach concentrates on some more attractive and appealing characteristics of the Wavelet Transform like multi scale correlation among the wavelet coefficients, local correlation among vicinity coefficients etc. The following two methods clarify the statistical properties of the wavelet coefficients based on a probabilistic model.

c) Marginal Probabilistic Model

The normally used Marginal probabilistic models under this group are Gaussian mixture model (GMM) and the Generalized Gaussian distribution (GGD).GMM is simple to use but GGD is more accurate.

d) Joint Probabilistic Model

Here Hidden Markov Models (HMM) and Random Markov Field Models are normally used. The disadvantage of HMM is the computational burden of the training stage hence a simplified HMM was proposed.

4.4.2 Data-Adaptive Transforms

Recently a new approach called Independent component analysis (ICA) has gained a significant importance include key component analysis, factor analysis, and projection detection. ICA is most widely used method for blind source partition problem. One advantage of using ICA is its assumption of signal to be Non-Gaussian which helps denoising of images by Non-Gaussian as well as Gaussian distribution. Few applications of ICA approach are machine fault detection, seismic monitoring, reflection cancelling, finding hidden factors in financial data text document analysis, radio communications, audio signal processing, image processing, data mining, time series forecasting, defect detection in patterned display surfaces, bio medical signal processing. limitations of ICA based approaches is the computational cost because it uses a sliding window and it involves sample of at least two image frames of the same scene as in [19].

V.CONCLUSION

Image denoising technique has been an everlasting research topic for researchers and one motive for this is the deficient of a solitary approach, which is competent to accomplish denoising for a broad category of images. However, conventional linear noise reduction approaches such as Wiener filtering, has been in existence for a long instant because of their simplicity and are capable to attain substantial noise elimination when the variance of noise is low, they cause blurring and smoothening of the sharp edges of the image. Therefore, presently there has been a considerable quantity of research on non-linear noise suppression methods and well-known amongst them are the wavelet based denoising approaches. Wavelet transform is most suitable for performance due to its properties such as sparsity, multiresolution and multi scale character, which wavelet is employed depends on the nature of the application. DWT has a limitation of Shift in varience while daubechies wavelet transform is competent to eliminate noise and a novel approach fast wavelet transform signifies with less memory obligation and less complication. Hence, knowledge of noise model and image denoising approaches is very significant part in image processing. To cater the need of this fundamental information in this paper a comprehensive review on noise models and image denoising approaches available has been carried out and presented. This presented work will provide a basic material for researchers especially the new entrants in the area of image processing.

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