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# A STUDY ON IMAGE NOISE AND VARIOUS IMAGE DENOISING TECHNIQUES

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## Abstract

Nowadays processing of the image is an emerging science. The image is contributed in several research fields such as biomedical, security, education, and space. The phenomenon of corruption in the images due to the noise is a big obstacle. The main two reasons for appearing the noise are transmission process from place to place or it may happen during the acquisition process. On the other hand, there are a lot of techniques for removing the noise and retrieving the image quality by manipulating the image data. In this article, a brief study on the major noise types is introduced. Also, the study consists of the famous de-noising techniques especially, the two essential methods spatial domain and transform domain with its subparts.

**Keywords:** Image noise, Denoising techniques, Spatial domain, Transform domain.

## 1. INTRODUCTION

The techniques of Image processing are applied in dozen applications widely for instance in medical imaging or scanning methods or even in printing skills and so on. However, the images have two form types as shown in figure 1, and the digital form is divided into three parts, each part may be used in a specific area. Images sometimes are damaged by the noise in the processes of image sending and receiving. The noise might badly affect the accuracy of the image and decrease its quality or clarity [1]. The quality improvement of an image has been a significant issue in the field of image processing. On the other hand, there are a lot of noise

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affection types [2]. The best definition of Image noise is known as any degradation in the signal of the image and the external disturbance is the major reason for that noise. Therefore, the most crucial field of restoring the images is the process of noise-cleaning or reduction. Noise reduction aims to ignore the pixels that known as noise in the image and although maintaining the edge and the original data of the master image. Realizing the features of interference or noise serves in finding the form of the noise that looks in an image and then removing it easily. Hence, effective de-noising methods turn a very significant role in the image processing field [3]. Filtering of noise is known as a process of exchanging all the pixels in the image that contain noise with a new value relying on the surrounding pixels. Several algorithms for filtering are being used and every algorithm varies from the others by the rate of detecting the noisy pixel from its neighboring pixels without affecting the original pixel [4]**.** This survey paper includes three parts, the first one is concentrated on the fundamental parts of noise form with brief illustrations of each one. The second part is focused on the latest movements and contributions about the techniques that are used in the image de-noising with presenting its major famous types in the present day. The final part is a short result analysis that shows the point of view which is being collected from different research paper on all filter techniques that related to the main two methods (Spatial domain and transform domain).

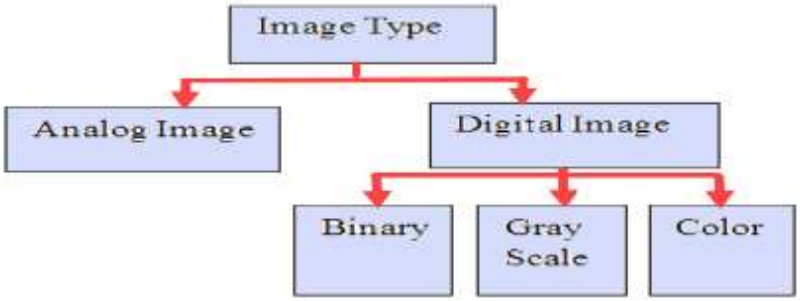


**Figure. 1. Image types.**

## 2. RELATED WORK

The researchers have done a huge amount of research papers on the subject of image noise types and de-noising methods. This part of the paper focuses on the latest movements and contributions of noise types and image de-noising algorithms and techniques from the latest research articles. R. Gondal & et al, 2021 [5] discussed many types of noise in mammogram images with showing various methods of image denoising. A. Nayak & A. Verma, 2018 [6] They give an

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elaborated search on several noise types and investigating the various techniques and their performances for de-noising issues in the image. However, S. Sumanth & A. Suresh, 2017 [7] explained some different mechanisms about noise model types and their effects on the digital image while image transmission. Also, talk about many image filter methods that are applied for image de-noising and then selecting the most suitable filter relying on the behavior of the noise. J. Nader & et al, 2017 [8]. Their article shows salt and pepper with Gaussian noises impacts and then after analytical observation, they get some methods to decrease mentioned noise. S. Tania & R. Rowaida, 2016 [9]. Provide new comparative research and empirical study on several models for enhancing the corrupted images by checking the performance for all applied models. G. Kaur & et al, 2016 [10]. They mentioned many noise approaches with their masks to discover and cleaning the noise. Different filters showed different results and some of them degrade the image quality and removed the edges. P. Athira & et al, 2016 [11]. Their paper mainly talks about the image in the biomedical research field and focuses on some noises in mammogram images with the way of de-noising M.Pious & et al, 2015 [12]. Introduced different noise cases that strike the image's quality and then express many effective de-noising forms. Because the noise sometimes not appears singly and maybe more than one noise type attack the images so, a few combined noise reduction methods are presented also. A. Ojha & N. Tiwari, 2015 [13]. Reviewed some various noise which leads to the image corruption, on the other hand, they show more than five techniques for retrieving the original image. S. Kaur, 2015 [14]. She separated her paper into some sections that talk about the form and the shape of the noise is and how it crawls to the images. Also introduced many algorithms for filtering the images. In the final parts of the research paper, different parameters are presented for comparing the performance of each filter type. A. Vijayalakshmi & et al, 2014 [15]. They Illustrate a broad work about de-noising models and their efficiency such as a brief comparison. In addition (B. Kaur & M. Shukla, 2014) [16]. Working on the noise patterns and a lot of filters with showing the pros and cons for every single one. Also, M. Farooque & J.Rohankar, 2013 [17]. They separate their articles into two-stage: noise and de-noise types and especially discussed wavelets method to prove that it can be applied for enhancing the images. In this paper, the focus will be on the major types of image noise and presenting imaginative, valuable types and methods of image de-noising that are used in the present time.

## 3. NOISE IN THE IMAGES

This section illustrates the image noise models, sources, and types in general.

### 3.1. NOISE Models

The noise might be in two form types in an image which is Additive or Multiplicative.

#### 3.1.1. Additive Noise Model:

Additive noise is the process of adding and then changing the original image to the pattern of a noisy image which means corrupting it. The next equation shows the additive noise model rule [18].

$$W(x,y) = S(x,y) * N(x,y)$$

W: Is corrupted Image.

S: Is the original Image Intensity.

N: Is the noise that introduced to produce the corrupted signal.

**Equation 1. Additive noise model rule.**

#### 3.1.2. Multiplicative Noise Model

Multiplicative noise is any unneeded random signal that becomes multiplied throughout the process of image capturing or transmitting and one of the examples of this noise model is the Speckle noise which mostly comes from the radar. The multiplicative noise model adopts the next rule:

$$W(x,y) = S(x,y) * N(x,y)$$

W: Is corrupted Image.

S: Is the original Image Intensity.

N: Is the noise that product the corrupted signal by Multiplication cause.

**Equation 2. Multiplicative noise model rule.**

### 3.2. Sources of noise

Noise in the digital image has a lot of reasons and sources such as [19]:

1- Deficiency in the level of light at the site of the location.
2- Image sensors may be one of the reasons when it comes under the impression of the environment at the clock of image acquirement.
3- The heat of the image sensor also it is a reason for some types of noise.

4- A slow shutter speed also permits the noise to enter.
5- The dust particles on the scanner screen may also corrupt the image.

### 3.3. Noise Types:

There are many types of noise in the image as shown in figure 2. The next subsections present each type separately.

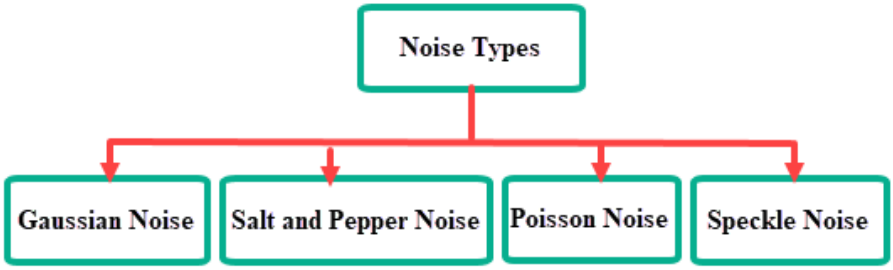


**Figure. 2. Noise types.**

#### 3.3.1. Salt and Pepper Noise

The impulse noise term is also utilized for this kind of noise [20]. Salt and pepper noise is also named impulse valued noise. Because of this noise black and white pixel appear in the image. The principal reason for the appearance of salt and pepper noise is: sharp and fast varies in the signal of the image, dust molecules in the image acquirement, and overheated elements. Whenever the image is corrupted by the noise that means the pixel values of the image are substituted with pixel values of the noise for instance the noisy pixel has either 0 or 255 value which is the maximum or 'minimum pixel value if the count of bits for transmission are eights. This type of noise inserts black and white dots on the images as shown in figure 3 [21] [22].

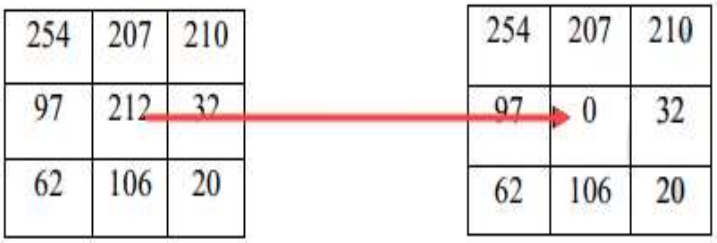


**Figure 3: Pixel in the center is corrupted by salt and Pepper.**

#### 3.3.2. Gaussian Noise (Amplifier Noise)

It has another name which is electronic noise since it grows in amplifiers or detectors [23]. Natural sources are the main reason for Gaussian noise, for

example, atoms thermic vibration or discrete form of radiation of heat objects [24]. In general, this type of digital image disturbs the gray pixels and it is a statistical noise that contains a function of probability density that equal to the normal distribution [25].

### 3.3.3. Poisson noise

This type also has the name of Shot photon noise [26]. Poisson or shot photon noise is the noise that may be produced in case son noise a group of photons is sensed through the sensor and consequently, it is not enough to supply noticeable statistical data. Poisson noise has a proportional value of root mean square for squaring the root intensity of the picture hence, a lot of pixels are corrupted by the value of the noise [27]. This noise type traces the distribution of Poisson that is normally slightly different from the Gaussian type.

### 3.3.4. Speckle noise

This noise is considered under the multiplicative noise type. Also, it exists inherently and causing degradation in the accuracy of the active radar images [28]. The reason for the speckle noise is the random fluctuations of bringing back the signal from an object in mainstream radar which is not large as a single element of image processing hence, it grows the grey level means of the local region. Image interpreting in SAR images is very hard because of the coherent processing of the scattered signals which is coming from different objects [29]. Speckle noise depends on the distribution of gamma [30].

## 4. Methods of Denoising

Generally, there are two basic methods for image de-noising which are Spatial Filtering and Transform Domain Filtering Method. The next subsection illustrates these two methods with it is techniques:

### 4.1. Spatial Filtering

The spatial filtering method is adopted in a case when only additive noise is available. Also, it can be categorized into 2 parts: Linear and Non-Linear Filters.

### 4.1.1. Linear Filters

In many situations that only additive noise is presented, we can select the linear method for an optimal solution. Mean filter is the best example of linear which is

used for dimming and removing Gaussian noise In addition, it also consists of Wiener filter [31]. The next subsections present two techniques that are related to linear filters.

### A. Mean Filter

Mean filter is a low pass linear filter and sometimes it is used for smoothing the images. It follows the procedure of windowed filter and the center value of the window is substituted with the average value. [32] The advantage of the mean filter is that applies processed neighboring pixel values previously to gain the best quality in the filtered image [33]. Figure 4 presents the basic concept of the Mean filter.

| | | |
|---|---|---|
| 5 | 2 | 6 |
| 4 | 1 | 5 |
| 1 | 1 | 2 |

3*3 window

AV = 5+2+6+4+1+5+1+1+2 /9 =3

| | | |
|---|---|---|
| 5 | 2 | 6 |
| 4 | 3 | 5 |
| 1 | 1 | 2 |

Mean Filtered Value

**Figure. 4 Basic concept of Mean filter by 3*3 window size**.

### B. Wiener Filter

This type of filter depends on the statistical way for filtering the noise that is damaged the signal so, we can gain the needed frequency response by applying this method. Also by the wiener method, we can perform the filtering process from different angles. But it is important to get the information about the spectral properties of the noise type as well as to the original signal for reaching the output that exactly such as the original image [34].

### 4.1.2. Nonlinear Filters

In any situation that only multiplicative and function noise is presented, we can select a nonlinear method for optimal solution [31]. In nonlinear filters, the process of ignoring or removing the noise is being done without identifying it and for acting that it is good to use the median for the pixel's neighbors to find out the

optimal output pixel value [35]. Furthermore, spatial filters remove the noise to a fair rate but the problem is the blurs that change the edges not visible inside the image. The next subsections present two techniques that are related to nonlinear filters.

### A. Median Filter

It is a filter that is particularly used for decreasing "salt and pepper noise", also it is used as a spatial filtering procedure that applies a two-dimension mask which is utilized for every pixel in the input image. The median filter maintains a sharp edge. on the other hand, the linear low pass filter dims the edges. Spiky noise is smoothed very efficiently by the median. Median is sometimes blurring the picture for larger window size plus that it is not sufficient noise remover for small window size and it has a good capacity to take out impulse noise without edges damaging so, it saves the edges [36]. The main disadvantage of the median filter is that it is efficiently working with low noise It is a filter that is particularly used for decreasing "salt and pepper noise", also it is used as a spatial filtering procedure that applies a two-dimension mask which is utilized for every pixel in the input image. The median filter maintains a sharp edge. on the other hand, the linear low pass filter dims the edges. Spiky noise is smoothed very efficiently by the median. Median is sometimes blurring the picture for larger window size plus that it is not sufficient noise remover for small window size and it has a good capacity to take out impulse noise without edges damaging so, it saves the edges [36]. The main disadvantage of the median filter is that it is efficiently working with low noise densities. Utilizing a median filter throughout the whole image schemes would surely change the intensities and maybe remove the details of the signal in the normal pixels [37]. Figure 5 is shown the method for finding the Median value.

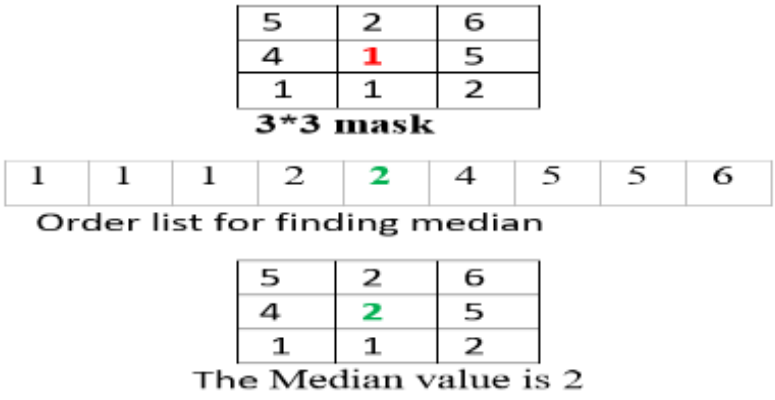


**Figure. 5 Concept of Median filter.**

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### B. Adaptive median filter (AMF)

AMF has been presented as an advancement of the standard median filtering because the median has a problem of removing fine pixels with the noise and it cannot distinguish between the fine details and the noise. Hence the principal idea in the Adaptive Median Filter is to execute spatial processing to decide which pixels in the image have been corrupted by impulse noise. So, it works only with an affected pixel. This procedure is done by applying the technique of pixels' classification, by making a comparison between each pixel in the image with it is neighboring pixels. The size of the neighborhood is adjustable and also the threshold for the comparing process. There are two conditions for deciding pixels' noise firstly, any pixel that is dissimilar to its majority neighbor's, Secondly, it must not be structurally aligned with those pixels to which it is alike or similar. These founded pixel noises are substituted by the median pixel value of the pixels in the neighborhood which is previously passed the test of noise. It is good to know that the outcome of the filter is one value utilized to substitute the pixel value at (x, y), the specific point on which the window Sxy is put in the center at a given time [38].

## 4.2. Transform Domain Filtering

This type is categorized basically into two types which are (Adaptive data transform and non-Adaptive data transform)

### 4.2.1. Adaptive data transform

This de-noising technique contains Independent Component Analysis (ICA). It is a new and rising technique that is getting interesting focus recently and introduced in [39]. ICA is a correlational analysis that searches on the signal's relation independency based on the greater order statistics it is opposed to the principal component analysis PCA that searches the correlation between signals according to the 2nd order statistics [40]. The ICA technique working in non-Gaussian information data and the behavior of the adaptive data types vary according to the features of the image within the filter. ICA Disadvantages when we compared with the wavelet technique are the cost of the computational since it applies a sliding window and it wants a sample of the free noise or two image frames of the same scene.

### 4.2.2. Non-adaptive data transform

Essentially non-adaptive data transform is categorized into two fields which are wavelet domain and spatial domain [6]. The next subsection presents two techniques related to the non-adaptive data transform filter.

### A. Wavelet Transfor

Wavelet domain has many benefits since the discrete wavelet transform DWT push the energy signal to focus only in a little coefficients number so, the DWT of a noisy image contains the number of coefficients giving big Signal to Noise Ratio (SNR) on the other hand comparatively big number of coefficients is giving low SNR. Afterward clearing the coefficients with small SNR and then the image is rebuilt by utilizing DWT inverse. Wavelet transforms at the same time provide the localization of Time and frequency. Furthermore, this method representing the signals more effectively than either Fourier transforms or the master domain [41]. The process of decomposition in any image is done by separating it into 4 subparts and these subparts are shaped by severable applications of (vertical, horizontal) filters. Subparts with the names LH1, HL1, and HH1 represent to latest coefficient scale while the LL1 subpart correspond to the coarse stage of coefficients [42]. The LL1 subpart is decomposed more and tried to discover the following coarse stage of wavelet coefficients and finally, it leads to 2 stages of the wavelet decomposition. Figure 6 shown the decomposition process entirely.

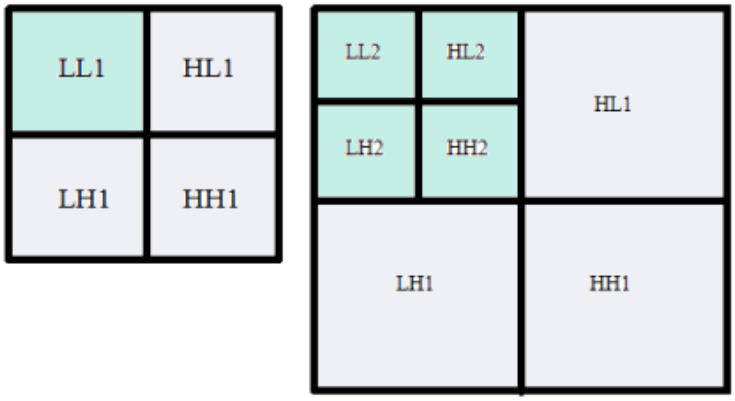


**Figure. 6 Decomposition of Image by DWT.**

Thresholding of wavelet is an estimation technique for the signal that takes the capacities of Wavelet-transform for noise removal from the signal. The process of removing the noise is done by ignoring the coefficients that are not relevant to

some threshold [42] A lot of researches are existed about thresholding the Wavelet coefficients and figure 7 illustrates the general phase steps of Image De-noising by WT.

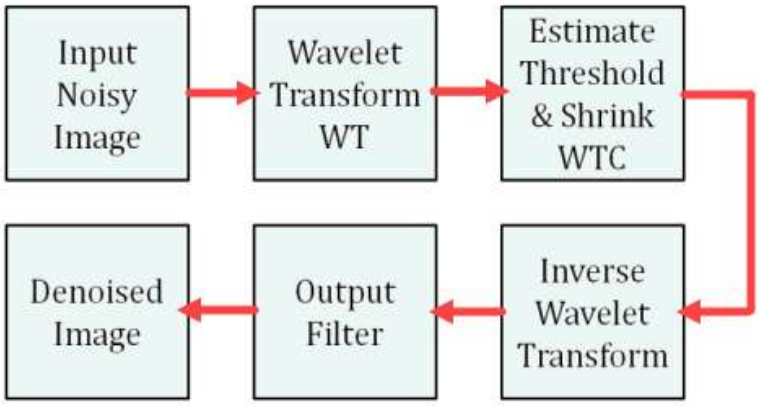


**Figure. 7 Procedures of Image De-noising by W.T.**

- Input the noisy image.
- Applying DWT on the noisy image for gaining coefficients of wavelet.
- Predicting the variance of noise from the image.
- Computing the value of threshold by several threshold choice rules.
- Utilize thresholding on the noisy coefficients (soft or hard thresholding).
- Applying DWT inverse to rebuilt the de-noised image.

### B. Spatial Frequency Domain

This method is utilized a low pass filter by applying Fast Fourier Transform (FFT) [43]. Before applying the filtering method, the noisy image is changed from spatial to the frequency domain using FFT. The drawback of these techniques is the consumption of time and it relies a lot on the behavior of filter functionality and the cut-off frequency which also leads to raise-up normal frequencies in the treated picture.

## 5. Results, Analysis, and Evaluations

Image de-noising consists of two approaches as shown in figure 8 which are spatial domain filtering & Transform domain filtering. A brief illustration of the way of working for these two mentioned approaches and the advantages of each one is shown in the table1. Furthermore, every single type has its techniques. Table 2 presents a brief description of the proprieties of some Spatial Domain De-

noising techniques such as Mean, Wiener, Median, and Adaptive Median. On the other hand, Table, 3 introduces a brief description of the proprieties of Transform Domain De-noising techniques such as ICA, Wavelet Transform, and Spatial Frequency Domain. Hence, after studying several research papers this article comes up with the following abbreviated analysis:

**Table 1. A brief illustration of Spatial domain filtering & Transform domain filtering methods.**

| De-noising Methods | The way of working | Advantages of the approach |
|---|---|---|
| Spatial approach | * Working directly.<br>* The processing speed rate is very high.<br>* Using simple tools for de-noising.<br>* it is categorized into linear and non-linear filters | * It can be used for smoothing the images also.<br>* Can be used for dimming the blur in the images because of linear movement.<br>* Easiest than Transform Domain in implementation & generally need less time. |
| Transform Domain approach | * Separated based on the basic functions into: -<br>Non-adaptive transform and adaptive transform.<br>*More complex than Spatial domain.<br>*Transform type primarily consist of wavelet filter methods. | * Used for de-noising Gaussian and Non-Gaussian distribution<br>* using the benefits of multi resolution properties of Wavelet Transform for gaining perfect de-noising. |

**Table 2. Brief description of some techniques within the Spatial Domain method.**

| Techniques within Spatial Domain De-noising method | A Brief description |
|---|---|
| Mean filter | *One of the linear tech.<br>* Utilizes processed neighboring pixel values to gain the best quality<br>*Not complex<br>* Utilized to reduce impulse noise<br>* The problem with mean does not maintain the image details. |
| Wiener filter | *Takes less calculation time.<br>* Depend on the statistical way in the filtering process.<br>* It can perform a filtering process from different angles. |
| Median filtering | * Without reducing the sharpness of the image can remove the outlier.<br>*Suitable for de-noising MRI images<br>* Median has a problem of removing fine pixels with the noise.<br>* The problem its Maintain the image edges. |
| Adaptive median filter | *Very effective because it's removes also the grain noise from the image.<br>* Do not have a problem removing fine pixels with the noise like median. |

**Table 3. Brief description of some techniques within the Transform Domain method.**

| Techniques within Transform Domain De-noising method | Brief description |
|---|---|
| ICA | *ICA is an Adaptive data transform.<br>* Working in Non-Gaussian information data.<br>* ICA Disadvantages, when we compared with the WT technique, is the cost of the computational process. |
| Wavelet Transform | *WT can be utilized for comparison in the performance due to sparsity & multiresolution.<br>* Provide the localization of Time and frequency |
| Spatial Frequency Domain | * Applying Fast Fourier Transform (FFT) for the filtering process.<br>* Disadvantages of this technique are consumption of time & raise up-normal frequencies in the treated picture. |

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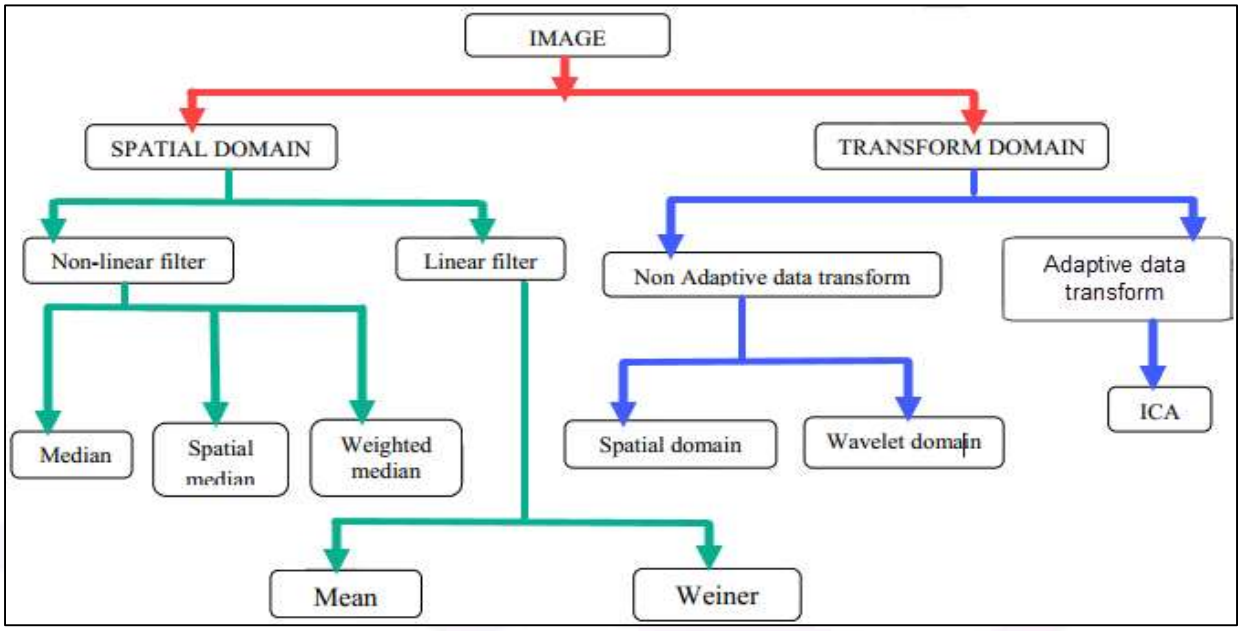


**Figure. 8 Categorization of De-noising Techniques.**

## 6. CONCLUSION AND FUTURE WORK

It is necessary to know some information's on the types of noise that corrupted the image to choose the desirable de-noising technique. So, selecting any technique that is utilized in the noisy image for the de-noising process is rely on the behavior of the noise. This paper is presented the basic noise models with the fundamental de-noising techniques. A brief review of the properties of the spatial domain method and transform domain method are illustrated as well as, the techniques under these two mentioned methods with showing the general features for each technique. This study concludes that there are a lot of techniques for image de-noising but there are also a lot of things that may occur in future researches for gaining the best accuracy and quality in the image filtering procedures. Further researches can find the optimal result and providing efficient solutions in this field.

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