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Comparative performance analysis of spatial domain filtering techniques in digital image processing for removing different types of noise

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Abstract

The reduction of the noise of the images always prevails as a challenge in the field of image processing. An image obtained after the elimination of noise has a higher clarity in terms of interpretation and study analysis in different fields such as medical, satellite and radar. This research work examines the various methods of de-noise images in the spatial domain and a comparison between several filtering techniques is carried out in the presence of different types of noise to achieve a high-quality image and to find the most suitable and reliable method for De-noising images. performance of all the filters is compared using parameters such as Mean Square Error (MSE), peak signal to noise ratio (PSNR).

Keywords: image Processing, noise Removal, filtering techniques, mean square error (MSE), signal to noise ratio(SNR), Peak Signal noise ratio(PSNR)
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1 Introduction

The main source of noise in digital images appears during the acquisition of images and / or transmissions. Imaging sensor performance is influenced by various environmental factors during image acquisition, and with the quality of the sensing element itself.

The general noise type that appears in the image is a) impulse noise, b) additive noise, c) multiplication noise. Different noises have their own characteristics that make it distinguished from others. Generally our focus is to remove certain types of noise. So we identify certain types of noise and apply different algorithms to eliminate noise.

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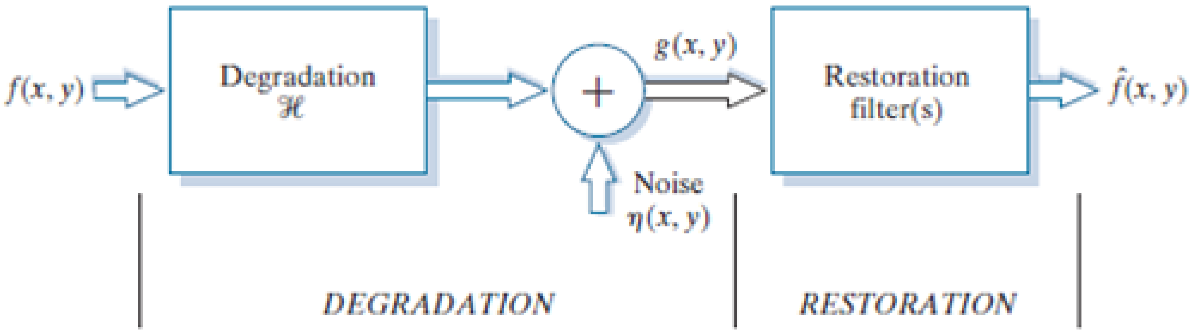

Figure 1: Image restoration process model

2 Types of noise in image

The different forms of noise are Gaussian noise, poisson noise, salt and pepper noise and speckle noise. These are not all noises that are encountered in an image, but it is the current noise encountered. The behavioural model of these noises is explained below.

2.1 Gaussian noise (Amplifier Noise)

Gaussian noise is also referred to as additive noise, it is called because each and every pixel is modified in such a way that certain distributions are added to each pixel. The most commonly observed distribution is the distribution of Gaussian or a bell curve. This is due to poor illumination during the capture or due to high temperatures. It can also cause noise in the electronic circuit. Gaussian distribution is always symmetrical. Gaussian noise usually occurs in amplifiers and detectors so that it is also known as electronic noise.

2.2 Impulse noise (Salt and Pepper noise)

Another name for salt and pepper noise is the noise of impulses (impulse noise). The reason for this noise is a sharp and sudden disturbance in the image signal, because it is also called the impulse noise. This is due to sudden disruption such as dust faulty charge coupled devices during the arrest of the image. The noise effect is only at small no. of Pixels, leave the remaining picture, not touched. Images with salt and pepper noise have dark pixels in bright areas and bright pixels in dark areas, white and black pixels are distributed randomly over noisy image.

2.3 Poisson Noise (Photon Noise)

Poisson or Shot Photon Noise is the noise caused when the number of photons felt by Senor is not enough to provide statistical information detected. Shot Noise presence because phenomena such as light and electric current consists of discrete package movements. The magnitude of this noise increases with the average magnitude of current or light intensity. This noise has the average root square value proportional to the intensity of the square root of the image. Different pixels suffered with independent noise values.

2.4 Speckle Noise

The noise speckle is a multiplication noise type. The noise of Speckle is generally found during the acquisition of images and transmission processes in synthetic aperture radar (SAR) images, satellite images, and medical drawings. Speckled noise consist of random values multiplied by the pixel value of an image. Speckle noise occurs because of interference caused by images during transmission and receipts. It produces bright and dark spots in the picture because of constructive and destructive disorders.

3 Noise removal filter in spatial domain

De-noising images are a very important task in image processing for image analysis. Algorithms of de-noising is available, but the best must remove the full noise from the image, while preserving details. The de-noise method can be linear and non-linear. Where the linear method is quite fast, but they do not preserve the image details, while non-linear methods preserve image details. Broadly, de-noising filters in the spatial domain can be categorized in the following categories:

3.1 Linear / mean / average filter

The mean filter is an average linear filter. Here the filter calculates the average value of damaged images in the pre-decided area. Then the value of the pixel intensity is being replaced with the average value. This process is apply for all pixel values of image.

3.2 Min Filter

Min filters are useful for finding the darkest point in an image. Also, reduce salt noise as a result of min operation.

$$\mathrm{f(x,y)} = \min_{\mathrm{(s,t)\in S_{xy}}} \{\mathrm{g(s,t)}\} \tag{3.1}$$

3.3 Max filter

Max filter is used for selecting the brightest points in an image. Because pepper noise has a very low value, reduced by this filter as a result of the selection of max, processing sub image area Sx,y

$$\mathrm{f(x,y)} = \max_{\mathrm{(s,t)\in S_{xy}}} \{\mathrm{g(s,t)}\} \tag{3.2}$$

3.4 Median filter

This filter is a static,and best non-linear filter, the response is based on the ranking of pixels values contained in the filter area. Here the center value of pixels is replaced by the median pixel value under the filter area.

3.5 Wiener- Filters

In the signal process, the Wiener filter is a type of adaptive filter used to provide the desired random process estimate or target with linear time-invariant (LTI) filtering noisy processes observed, assuming stationary signals and additives noise , and noise spectra. If the variance is smaller, Wiener does a better smoothing and if the variance does a little alignment. Adaptive filters are more selective than linear filters because they maintain edges and other high frequency parts of an image. Wiener filters provide statistical estimates of unknown signals using relative signals as input and use known signals to produce estimates as output.

3.6 Gaussian filter

Gaussian filter is a linear filter. Usually used to obscure images or reduce noise. If you use two of them and subtract, you can use it for "Unsharp Masking" (edge detection). Gaussian filters alone will obscure the edges and reduce contrast.

3.7 Guided filter

Filter Guided Making the Shipping Edge, Smoothing the image, using the second image content called guide image, to influence the filtering. Guide images can be the image itself, different versions of images or completely different images. It takes into account the statistics of a region in the spatial environment that is appropriate in the guidance image when calculating the output pixel value.

3.8 Block Matching and 3D (BM3D) Filter

This denoising technique of this image is depend on the filtering effective in the 3D transformation by combining sliding window transformation processing with matching blocks. We process blocks in pictures by sliding and utilizing the concept of blocking by finding blocks similar to those currently processed. Blocks that are suitable are stacked together to form a 3D array and because of the similarity between them, the data in the array shows a high correlation rate. We exploit this correlation by applying a 3D unified transformation that does not correlate and effectively thinn the noise by shrinking the transformation coefficient.

3.9 Noise adaptive fuzzy switching median (NAFSM) filter

This filter is a median filter with adaptive fuzzy switching. Initially, the detection stage would use the damaged image histogram to identify noise pixels. This detected "pixel noise" will then be subject to the second stage of filtering, while "free pixels noise" is returned and left unprocessed. Then, the filter uses fuzzy logic to handle uncertainty in local information extracted as introduced by noise.

4 Performance measurement parameters

4.1 Mean Square Error (M.S.E.)

The lower the value of MSE represents lower the error.

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{0}^{\mathrm{M}-1} \sum_{0}^{\mathrm{N}-1} [\mathrm{f}(\mathrm{x}, \mathrm{y}) - \mathrm{g}(\mathrm{x}, \mathrm{y})]^2 \tag{4.1}$$

4.2 Peak Signal to Noise Ratio (P.S.N.R.)

The PSNR is defined as the ratio of the maximum pixel intensity to the mean square Error. PSNR is defined in logarithmic decibel scale. Higher value of PSNR represnts a good quality image.

$$\mathrm{PSNR} = 10 \log_{10} \left[\frac{\mathrm{M} * \mathrm{N}}{\mathrm{MSE}} \right] \tag{4.2}$$

5 Methodology

6 Experimental Results and Analysis

The experiment was carried out in the standard Gray scale image of the "cameraman" size of 256 x 256.Simulation was carried out using the R2016A MATLAB software. Broken input images by simulated salt and Pepper noise (noise density = 0.05), noise white gaussian (mean = 0, variance = 0.01), noise poisson, noise speckle (mean = 0, variance = 0.04). For denoising processes, various filters Like linear filters (3x3) Median filters (3x3), Min Filter (3x3), Max Filter (3x3), Wiener Filter (3x3), Gaussian Smoothening Filter,BM3D-Filters (3x3), adaptive fuzzy switching quantitative performance filters are evaluated through figure below

7 Conclusion

It's hard to say which filter is the best among all filters but depending on the type of noise, the filter can be used, after the comparative analysis of the noise removal technique is done. Investigate the results by applying various types of noise to the image model, the following conclusions are created: Filter matching blocks (BM3D) found stable and comprehensive.

We also observed that the median filter worked very well for the salt and pepper noise and Gaussian noise. Linear filters work very well for the Poisson noise. Wiener filters have been done well for the Poisson noise, also salt and peppers, Gaussian, Poisson, and speckle noise are moderately work for min and max filters. A guided filter does a very good job with Poisson noise. Fuzzy adaptive median filter has been proven best for salt and pepper noise. Finally draws the conclusion that the BM3D filter is a strong filter that has worked very well with all types of noise.

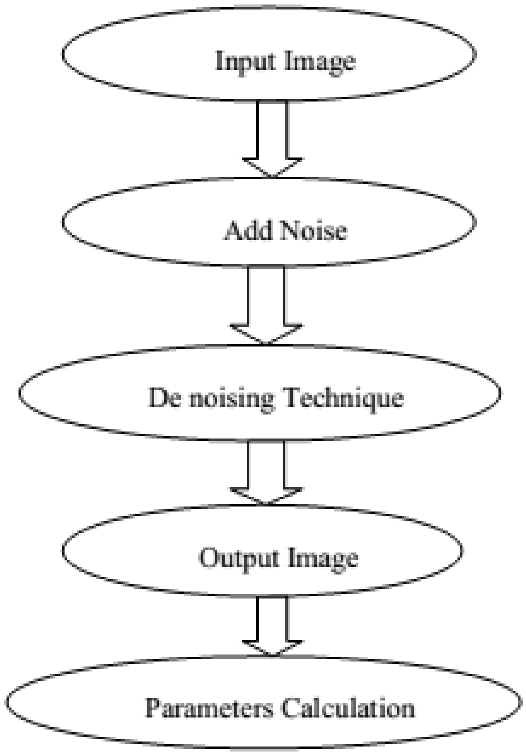

Figure 2: flow chart of methodology

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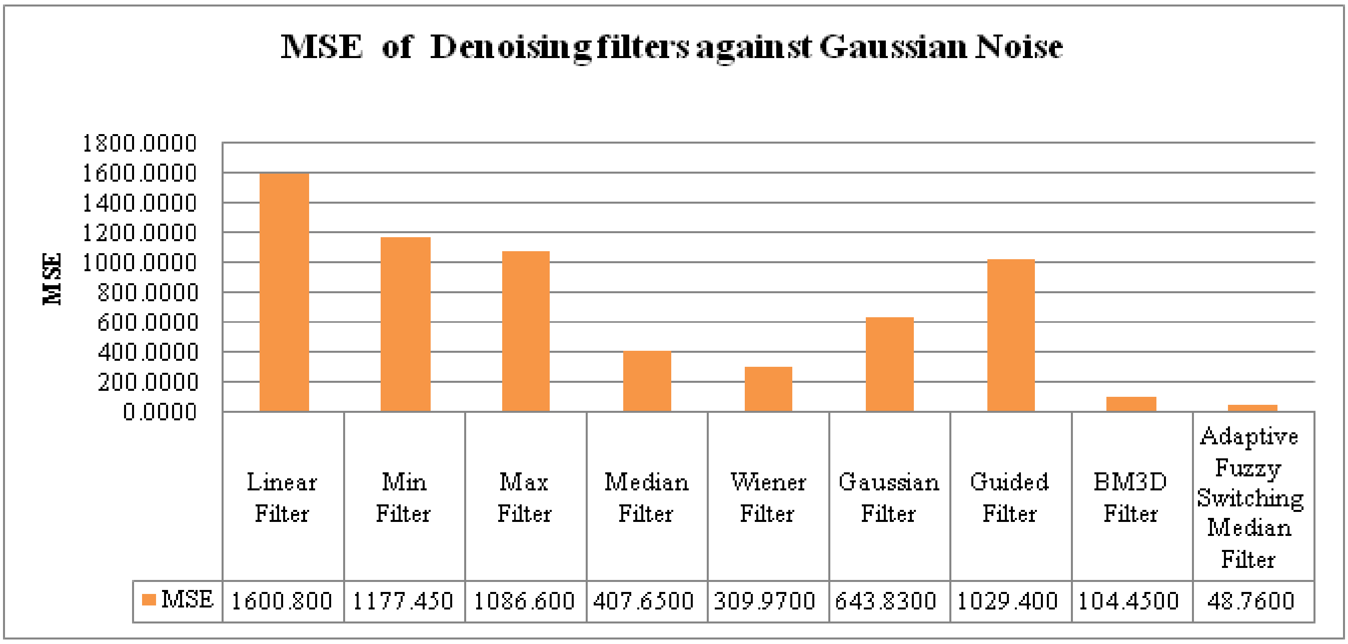

Figure 3: Comparison between MSE of denoising filters against Gaussian noise

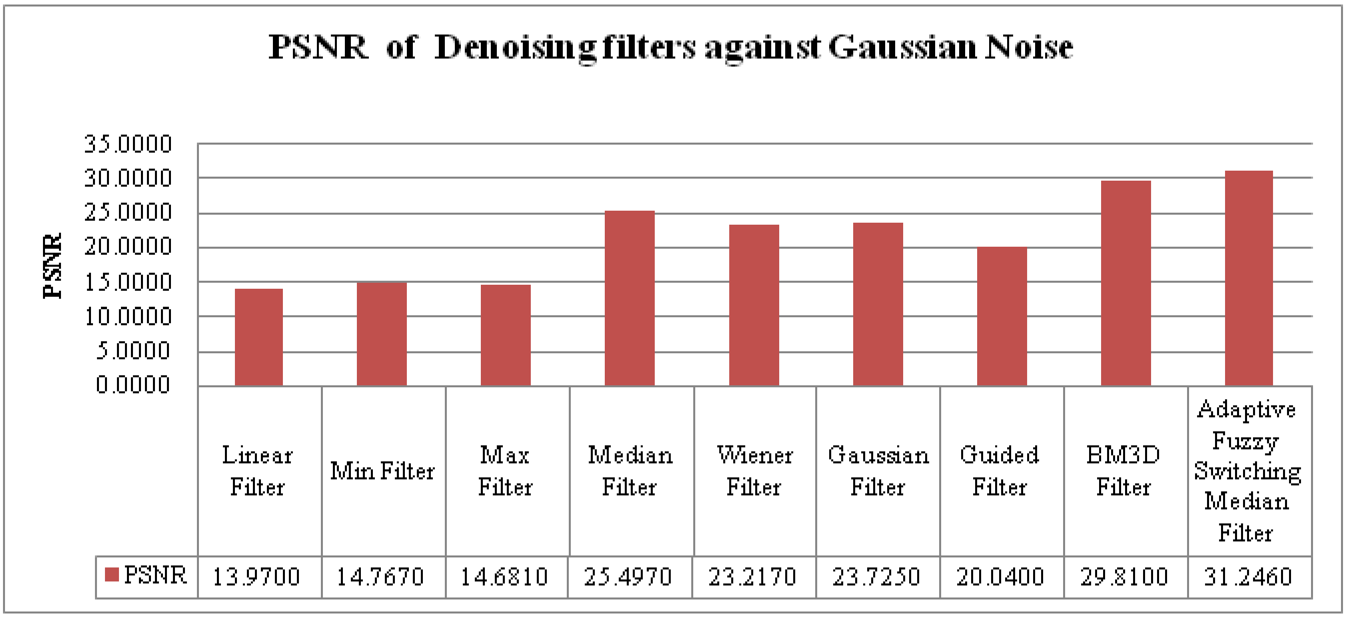

Figure 4: Comparison between PSNR of denoising filters against Gaussian noise

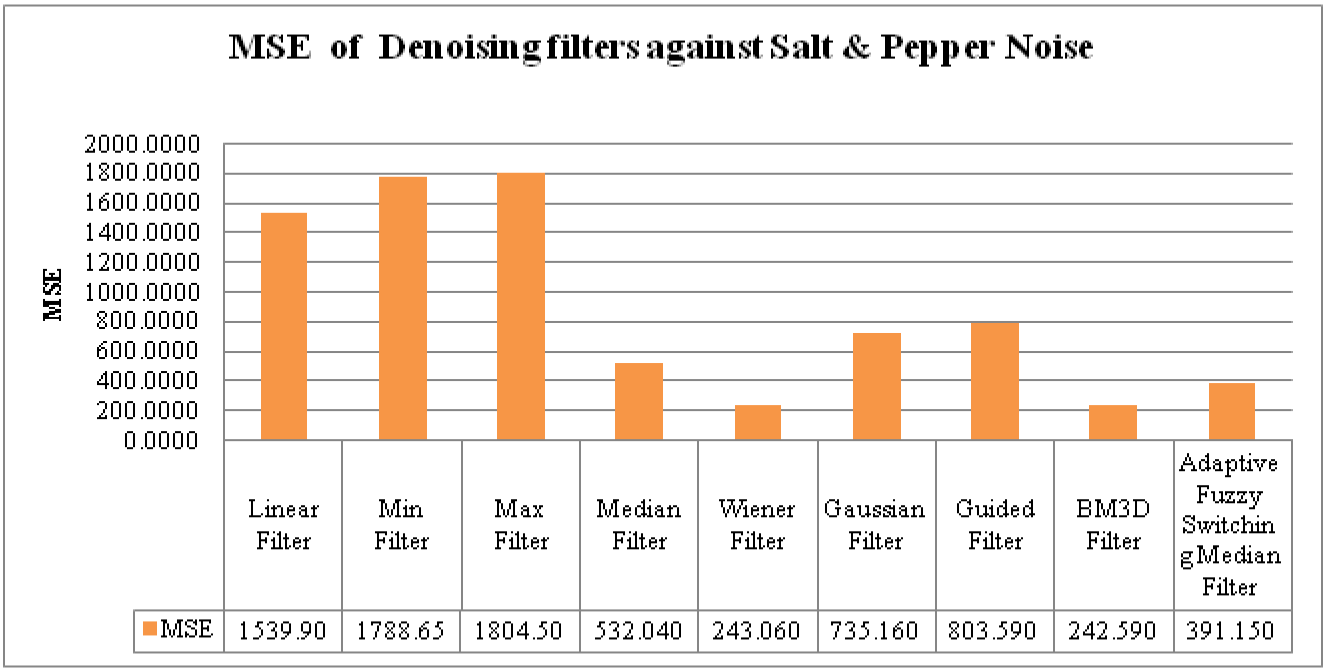

Figure 5: Comparison between MSE of denoising filters against Salt and pepper noise

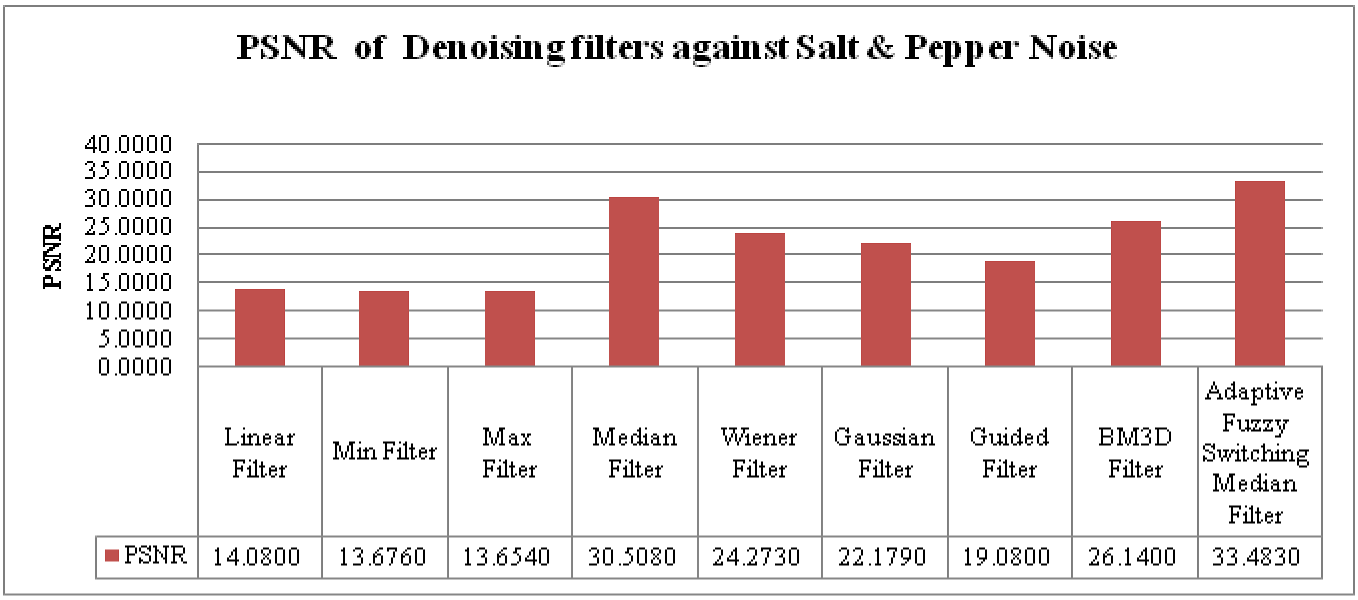

Figure 6: Comparison between PSNR of denoising filters against Salt and Pepper noise

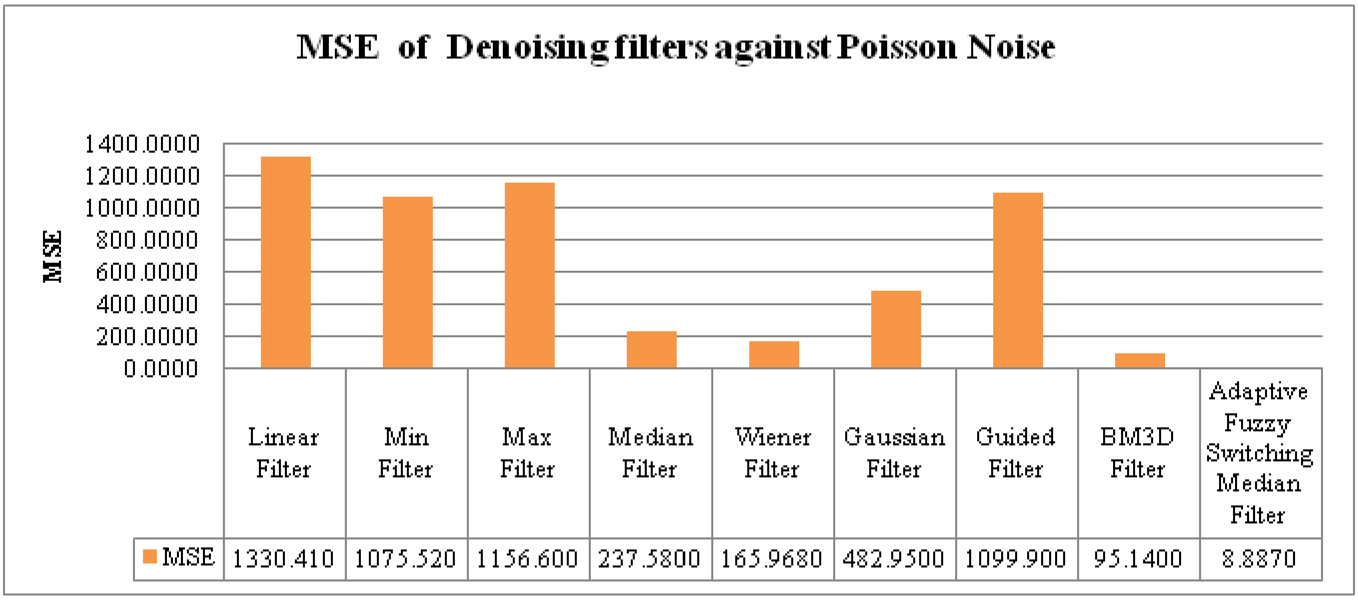

Figure 7: Comparison between MSE of denoising filters against Poisson noise

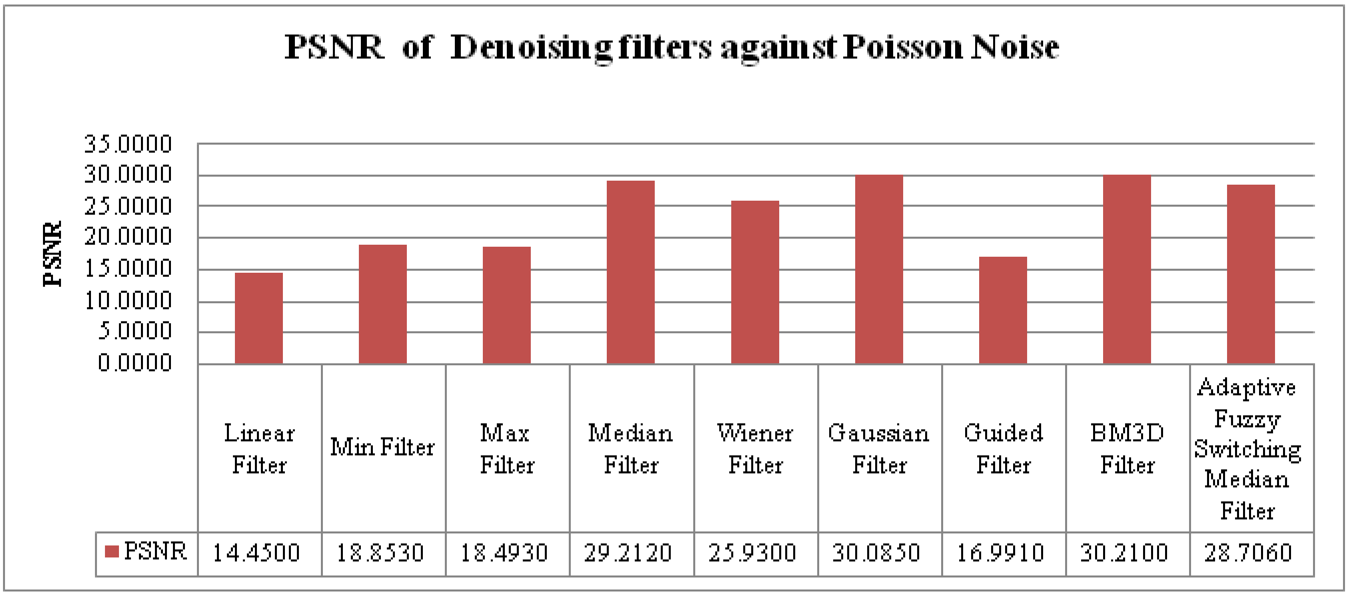

Figure 8: Comparison between PSNR of denoising filters against Poisson noise

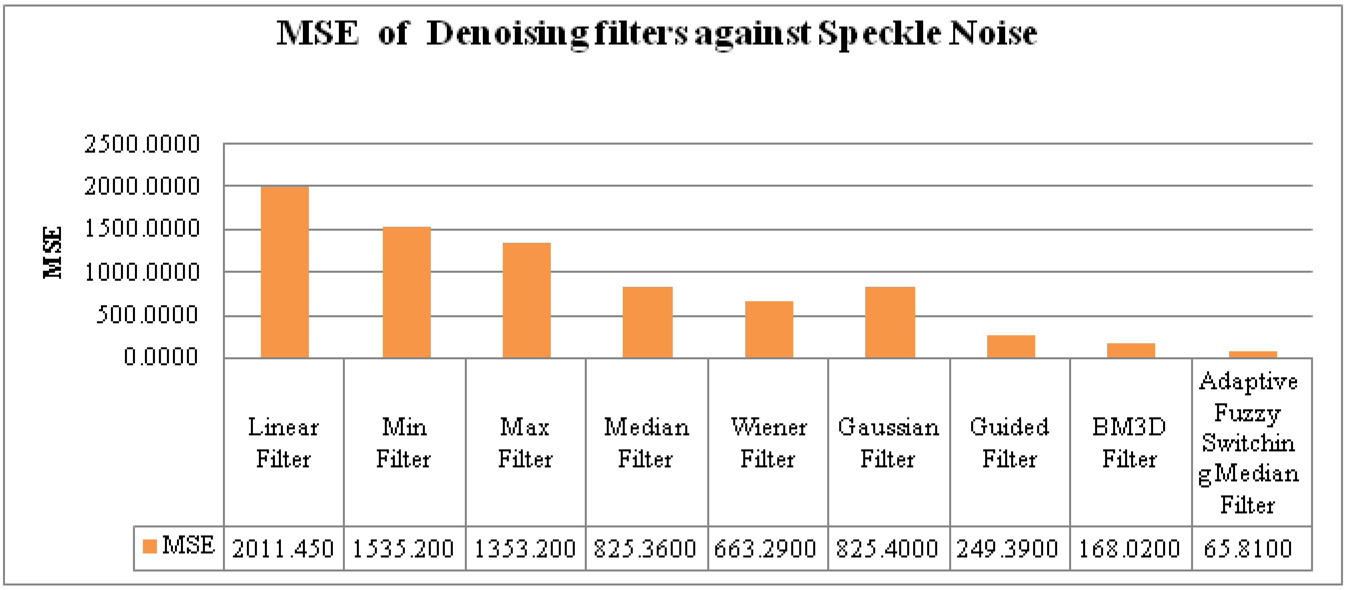

Figure 9: Comparison between MSE of denoising filters against Speckle noise

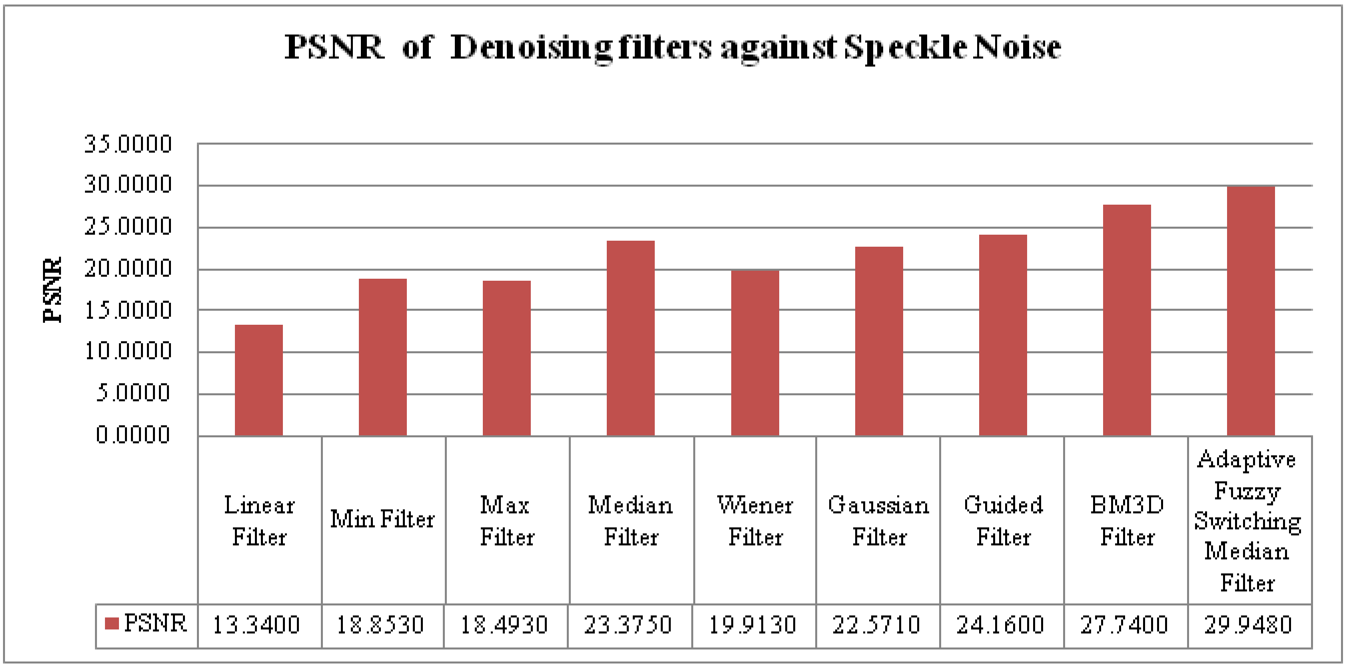

Figure 10: Comparison between PSNR of denoising filters against Speckle noise