Performance Analysis of Filtering Methods in Denoising of Mri Images

B. Sangeetha

Abstract: ***Biomedical Image Acquisition (BIA) system provides vital information relating to anatomy of the human body and present quantitative image analysis which assists the doctors in diagnosing disease and treating the patients efficiently. Magnetic Resonance Imaging (MRI) is one of the tool utilised frequently for brain related diagnosis. However, the images obtained through MRI scans are subjected to the noise interruptions. Mostly, the MRI images are suffered from salt and pepper noise, Gaussian noise and Speckle noise. Hence, to overcome these noise interruptions, a comparative study on the filtering topologies namely Median, Anisotropic, Lee and Frost filters have been discussed in this work based on their Performance Evaluating Parameters-PSNR, MSE and SSIM. These performance of the filters were tested over three different dataset. From the results, it is concluded that the median filter exhibits higher performance salt-pepper noise whereas for speckle Nosie, frost filter exhibits better performance and all the four filter exhibits liner performance over thefor Gaussian filter.***

Keywords: ***Biomedical Image Acquisition, Magnetic Resonance Imaging, Median, Anisotropic, Lee and Frost filters***

I.INTRODUCTION

Magnetic Resonance Imaging (MRI) technique plays a vital role in a medical field and its related research works. It helps the doctors and radiologists to analyse the human brainand simplicities the work in diagnosing brain related problems and treatment. Hence, it is deserved as a safest diagnostic tool for brain tumor detection. However, these MRI images exhibit inhomogeneity and poor quality due to the presence of noise in it.It can be subjected topresence of some unwanted noises such as speckle noise, Gaussian noise and salt and pepper noise etc., These noise may also degrades the performances of Feature Extraction, segmentation and classification of the processed image. Hence the noise has to be filtered before they are processed to processing stages. So far, many image filtering algorithms has been proposed for filtration of MRI images. A denoising method using WaveAtom Shrinkage in MRI image was proposed by Rajeeshet al 2010. This was tested over the cardiac and brain MR images which are suffered from lower SNR. This improves the SNR of the images. A Non-Local Means (NLM) were designed to filter a random noise in MRI images[2,16]. As this filter highly depends upon parameter setting, this was simulated to find out optimum parameters for various noise levels.

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***** Correspondence Author
B.Sangeetha, Professor, AVS Engineering College, Salem, Tamilnadu.

In general, this filter was applicable for both synthetic and real images. The same filtering topology was proposed byLiu et al and it is appliedover 3D MRI images. From the experimental results,it is proven that this filter exhibits better denoising performance compared over the other filters.Combined Bilateral and Anisotropic-DiffusionFilters was proposed by Arif SamehArif et al 2011. This method was analysed over 23 MRI images. From the results analysis, it is concluded that this method gained higher PSNR and CR performance incomparison with traditional methods. Similarly, wavelet basedfilters have been tested over MR denoising [6-10]. The FFT/ DCT also have been applied for denoising process in MRI. In this topology, sin / cosine functions are utilised to representthe images. It removes the noiserelatedcoefficients in the transform domainusing thresholding techniques[12]. In 2015, DCT-based filter with a PCA topology was adopted for denoising in MRI [11]. This filter was able to deal with varying noisepatterns. Bhausaheb Shinde *et al*, proposed various filtering technique such as median, adaptive and average filter to remove speckle noise in MRI image. The resultsrevealed that noise removal depends upon the type of noise and also on the filtering topology.Hence the right selection of suitable filter for noise will save the processing time and easy medical diagnosis [4].Sivasundari*et al* conducted a test over the performance of filtering topology for MRI denoising. It includes Median filter, Center Weighted Median filter and Weiner filter. From the final analysis, it was proven that Weiner filter have large PSNR value and ensures the high image enhancement[5]. Based on this literature survey, no method has shown to be superior to all types of noises. Hence, this study presents a four different denoising topology to remove the noises presentin MR images.Thus, this work evaluates the performance ofproposed filtering topologiesfor three different noises at noise density varying from 10- 90%. Finally, the performance indices of the proposed filtering topology is measured in terms of PSNR, MSE and SSIM parameters.

II.MATERIALS AND METHODS

Noise is defined as the unwanted fluctuations caused in the images which in turn reduces the quality of images. It may occur due to sensor error/ disturbances during data transmission. Thus the type of noises that generally occurs in MRI images can be categorized as

a. Speckle noise
b. Gaussian noise
c. Impulse noise

Among these, speckle noise is mainly due to transmission errors[21]. Gaussian noise is referred as amplifier noise.

These noises are independent of pixel and its intensity. It has constant noise level in dark areas of the image. Similarly, a salt-and-pepper noise will have dark and bright pixels in the alternate bright and dark regions.Hence, to eradicate the effects of these noise over the MRI images, various types of filters are introduced. In this work, performance of four different types of filters are analysed for different MRI images. Thus the four different types of filters are considered for this study are described as follows

Median Filter (MF)

The MFadopts a non-linear filtering method. It preserves the features at the edge and sharpness of the image. It is more suitable for impulse noise.In thisfiltering, the pixel values in the neighborhood window (ω) are rearranged on the basis of intensity and itsmedian value [22].

$$y[m,n] = median\{x[i,j],(i,j) \in w\}$$

Where

ω - neighbourhood

It is less sensitive to extreme values.

Anisotropic filter (AF)

Perona and Malik [26], formulated a new multiscale smoothing and edge detection scheme for image pre-processing. Thus, this AF is mathematically considered as a diffusion process, it performs an integral smoothing over the boundaries. In this topology, the estimation of the image structure is carried out by their statistics of the noise degradation and the edge strengths[14,17].

Lee filter (LF)

LF is one of the popular filter modelled specifically for despeckling and enhancing images. It utilizes minimumMMSE criterion to perform despeckling [18,20].

The procedure adopted in the Lee filter are as follows

1. It takes the reference image, /noisy image and the window size as input and performs the following steps.
2. The variance of the reference image is calculated.
3. Based on the size of the kernel, the noisy image is padded with zeros on all sides.
4. The center index of the kernel is found.
5. The noisy image is processed patch by patch.

The Frost filter

Similar to theLee filter and the Kuanfilter[15], the Frost filter is also based onthe minimum mean square error criterion. However, differentfrom the Lee and Kuan filters, the Frost filter does not own asimple linear weighted form of the real image and the observedimage. The Frost filter has the following expression:

$$DN = \sum_{n \times n} K\alpha e^{-\alpha|t|}$$

Where

$$\alpha = \left(\frac{4}{n\,\bar{\sigma}^2}\right)\left(\frac{\sigma^2}{\bar{I}^2}\right)$$

K= Normalized constant

n = moving kernel size

Filters Performance Measurement

There are two types of metrics are utilised to evaluate the performance of the filter [24]

(a) Error Sensitivity Measure (ESM)

(b)ImageQuality Assessment (QA).

Among these, ESM is widely considered to evaluate the performance of the filters. It includes

Mean Squared Error (MSE),

Signal-to-Noise Ratio (SNR)

Peak Signal-to-Noise Ratio (PSNR).

MSE

It is computed by averaging the squared intensity of theinput image and the restored image.It can be represented as[25]

$$\mathrm{MSE} = \frac{1}{MN}\sum_{n=0}^{M}\sum_{m=1}^{N}\left[\hat{g}(n,m) - g(n,m)\right]^2$$

Similarly, SNR and PSNR are calculated for quantifying the image contrast.

SNR

This measures level of noise present in the image. It is the ratio of mean to the standard deviation of pixel amplitudes in an image.

$$SNR = 10\ log_{10}\frac{\sigma_g{}^2}{\sigma_e{}^2}$$

PSNR

PSNR isdefined as relative to peak dynamic range i.e. 255 for an 8 bit image. The PSNR is used to measure the quality of an image afterthe reconstruction in which higher a PSNR indicates a good reconstruction and hence, ensuring a high image enhancement[15].

$$PSNR = 20log_{10}\left(\frac{255}{RMSE}\right)$$

PSNR is expressed in dB and formulated as in (6) where *L* is the dynamic range of the pixel intensities

SSIM

This index measures the similarity between two images. This metric exhibits better consistency with the qualitative appearance of the image.

$$SSIM = \frac{1}{M}\sum\frac{(2\mu 1\mu 2+C1)(2\sigma_{1,2}+C_2)}{(\mu_1{}^2+\mu_2{}^2+C_1)(\sigma_1{}^2+\sigma_2{}^2+C_2)}$$

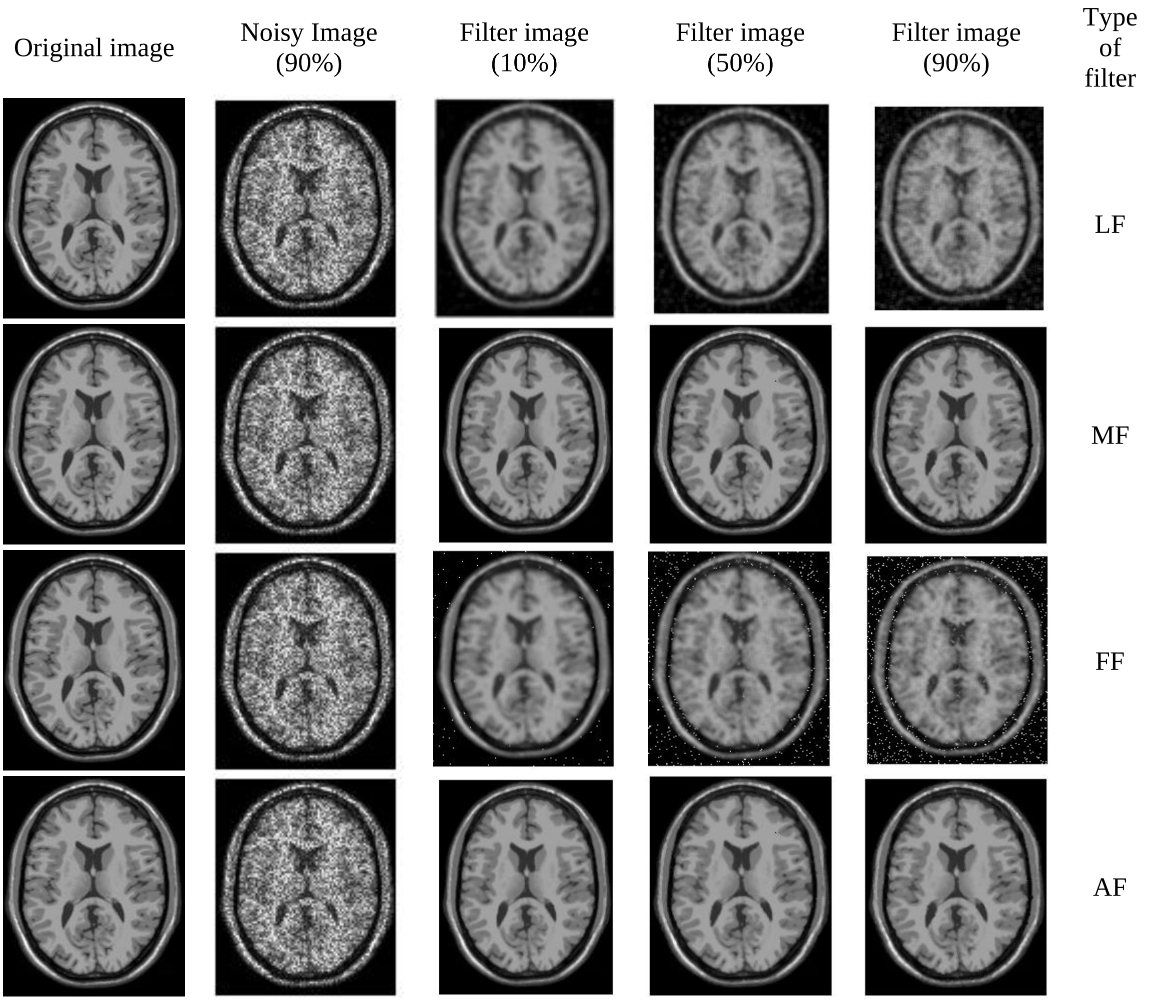
III.RESULTS AND DISCUSSION

In this section, two different analyses namely qualitative and quantitative analysis are carried out in this work for three different dataset of MRI images. Three types of noises ranges from 10% to 90% (Salt and pepper, Speckle and Gaussian) are introduced in these dataset. To remove this noise, four different filters namely MF, AF, LF and FF have been implemented. To evaluate the performance of these four filters, three different dataset were utilised.

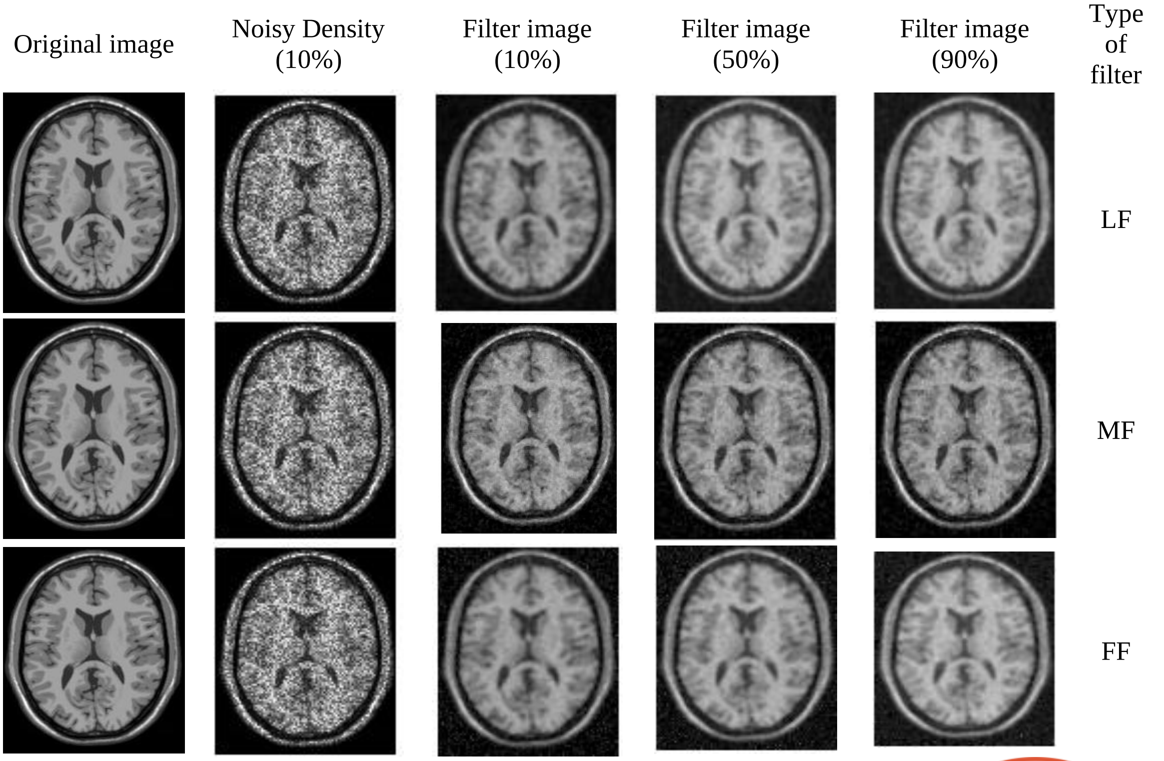
Case study (I)

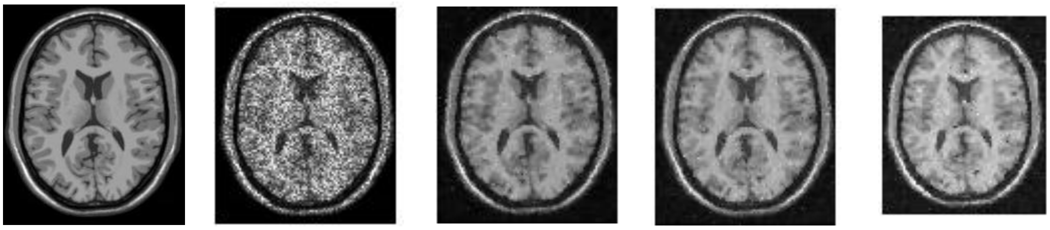
Analysis over Brainweb dataset

In this study, MRI data set were downloaded from https://brainweb.bic.mni.mcgill.ca/.This dataset contains simulated brain MRI data based on two anatomical models: normal and multiple sclerosis (MS). For both of these, full 3-dimensional data volumes have been simulated using three sequences (T1-, T2-, and proton-density- (PD-) weighted) and a variety of slice thicknesses, noise levels, and levels of intensity non-uniformity.



1a.Salt and Pepper Noise

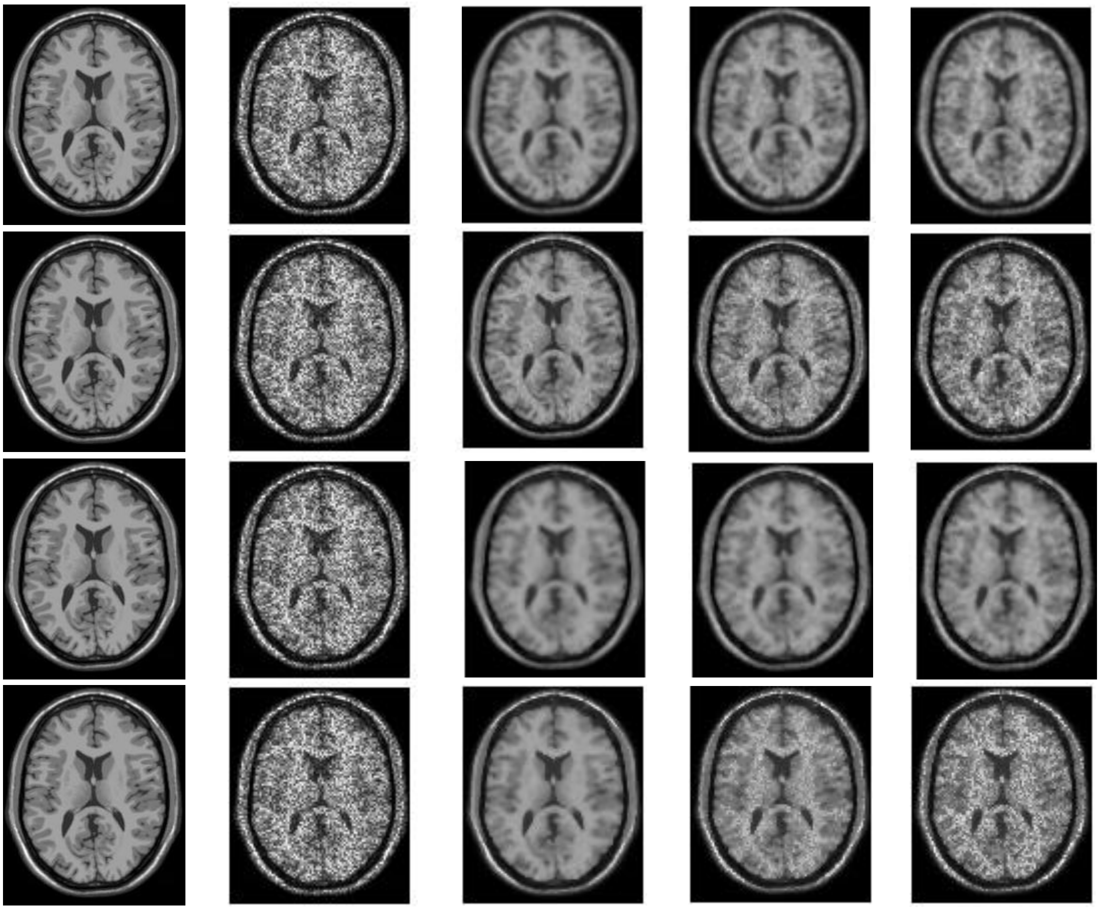




AF

1b.Gaussian Noise

Original image | Noisy Density (10%) | Filter image (10%) | Filter image (50%) | Filter image (90%) | Type of filter



LF

MF

FF

AF

1c.Speckle Noise

Figure 1a-1c depicts the performance of the projected filters for brain web images under three noise density level (10%, 50% and 90%). From the visual representation, it is proven that MF showsbetterimage quality for SPN. For the SN removal, FF exhibits better quality of image compared to other filters. This visual elucidationis confirmedwith quantitative measurement (PSNR,MSE and SSIM)of each filters.

Table 1displays average PSNR values of MF,AF, LE and FF for three types of noises (GN, SPN and SN). The noise density is varied from 10% to 90%.

Table.1a.Salt and Pepper noise

Noise (%)	MF	AF	LF	FF
10	83.46	72.39	74.44	72.02
20	83.16	69.42	74.11	71.05
30	82.90	67.74	73.77	69.42
40	82.38	66.76	73.3121	68.92
50	82.15	65.98	72.92	67.77
60	81.70	65.16	72.52	67.45
70	81.96	64.51	72.21	66.69
80	81.50	64.01	72.06	66.08
90	80.96	63.70	71.57	65.98

Table.1b. Speckle Noise

Noise (%)	MF	AF	LF	FF
10	79.01	78.31	74.69	74.79
20	77.05	77.53	74.57	74.82
30	75.75	76.09	74.42	74.89
40	74.77	74.58	74.27	74.85
50	73.96	73.03	74.18	75.05
60	73.19	71.74	74.00	74.94
70	72.86	70.78	73.92	74.90
80	72.86	69.91	73.85	74.73
90	71.71	69.20	73.75	74.70

Table.1c. Gaussian Noise

Noise (%)	MF	AF	LF	FF
10	74.72	73.46	73.05	73.111
20	73.21	72.88	72.57	72.62
30	72.38	72.29	72.00	71.96
40	71.38	71.47	71.31	71.43
50	71.50	70.75	70.57	70.64
60	70.53	69.97	69.86	69.96
70	69.58	69.19	69.05	69.25
80	68.78	68.38	68.36	68.51
90	67.98	67.72	67.66	67.86

Table 1.Average PSNR values of MF, AF, LE and FF

Table 1a-c tabulates an average PSNR for each tested filters and the results revealed that MF exhibits higher PSNR for SPN whereas FF exhibits higher PSNR forall levels of noise density compared to other filters. In case of GN, LF shows better performance than other three filters. Figure 2a-c depicts the SSIM.

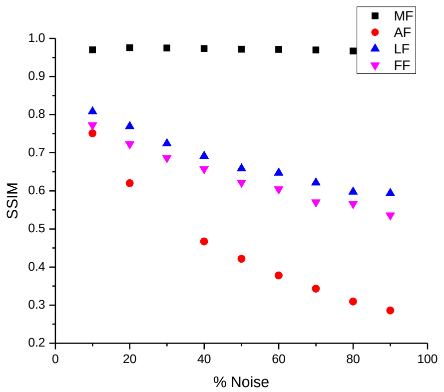


Figure 2a. Salt and pepper Noise

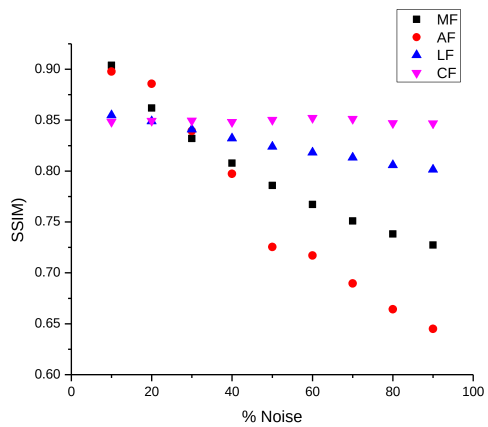


Figure 2b. Speckle noise

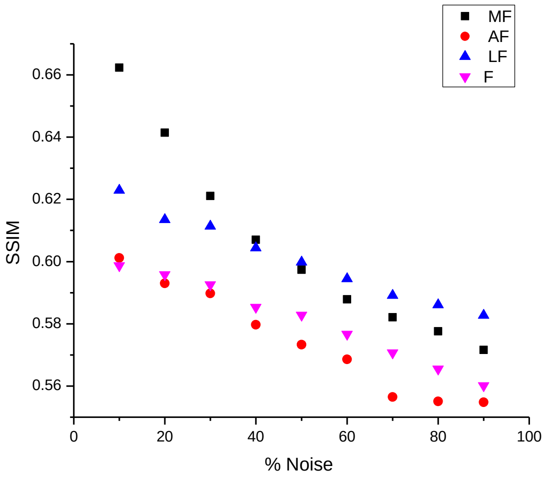


Figure 2c. Gaussian noise

Figure 2a-c SSIM value of filters.

From the graphical analysis, it is found that the MF exhibits higher similarity value for all levels of noisy density. For the speckle noise removal, FF exhibits higher accuracy whereas more or less all the filters exhibits same accuracy for Gaussian noise.

Case (II) -E health database

In this study, MRI data set of brain T2-weighted MR images are acquired from symptomatic untreated multiple sclerosis (MS)subjects which were downloaded from http://www.medinfo.cs.ucy.ac.cy/. Figure3a-c tabulates an average PSNR for each tested filters and the results revealed that MF exhibits higher PSNR for SPN whereas FF exhibits higher PSNR forall levels of noise density compared to other filters. In case of GN, LF shows better performance than other three filters. Figure 4a-c depicts the SSIM.

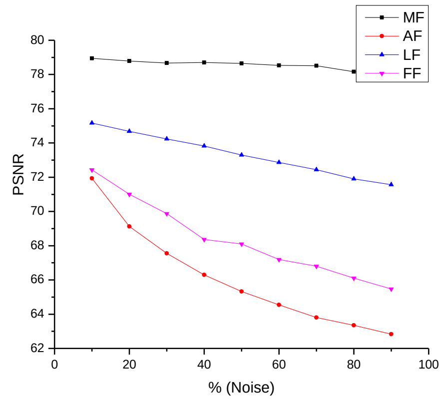


Figure 3a. Salt and pepper Noise

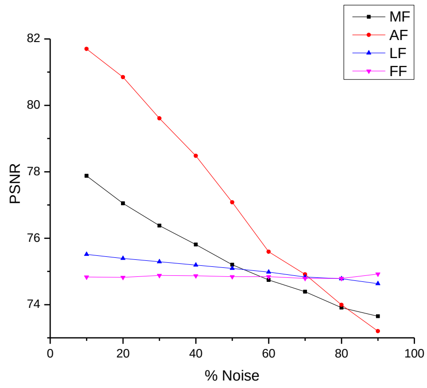


Figure 3b. Speckle noise

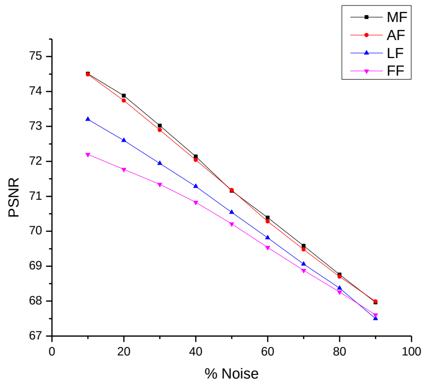


Figure 2c. Gaussian noise

Figure3a-c Average PSNR Value

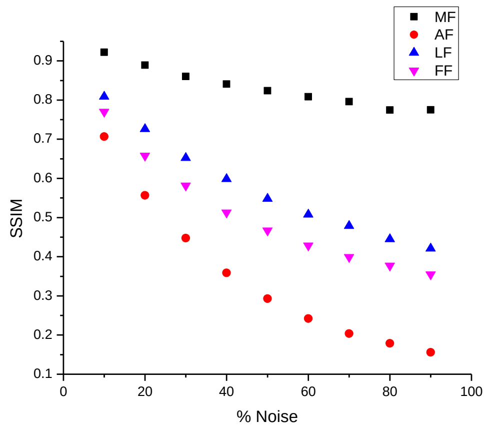


Figure 4a. Salt and pepper Noise

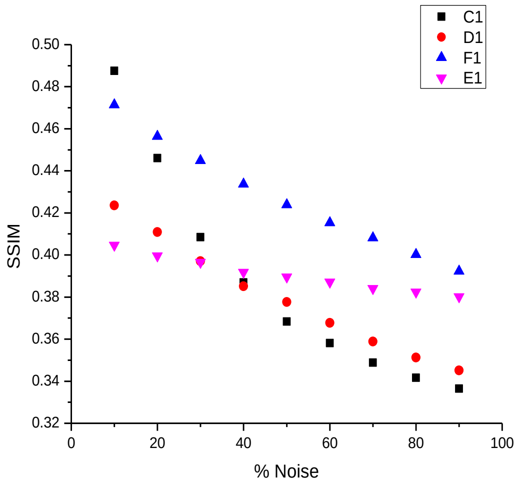


Figure 4b. Speckle noise

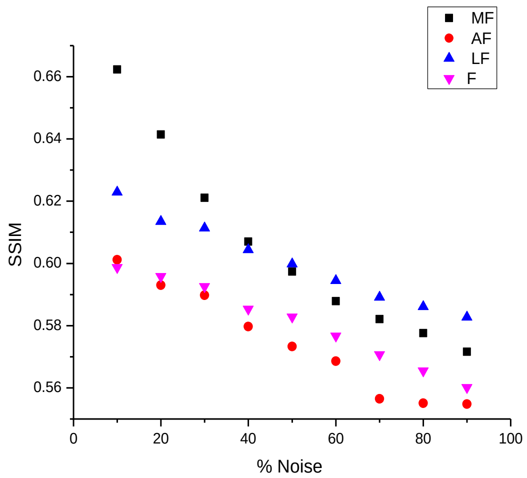


Figure 4c. Gaussian noise

Figure 4a-c SSIM value of filters.

From the graphical analysis, it is found that the MF exhibits higher similarity value for all levels of noisy density. For the speckle noise removal, FF exhibits higher accuracy whereas more or less all the filters exhibits same accuracy for Gaussian noise.

Case (II) –BRATS 2013 database

In this study, MRI data set of Brats 2013 is considered for analysis.Figure5a-c tabulates an average PSNR for each tested filters and the results revealed that MF exhibits higher PSNR for SPN whereas FF exhibits higher PSNR forall levels of noise density compared to other filters. In case of GN, LF shows better performance than other three filters. Figure 6a-c depicts the SSIM.

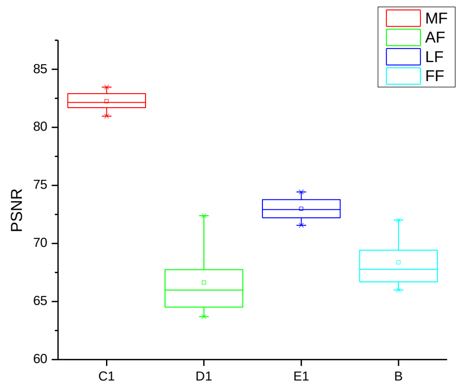


Figure 5a. Salt and pepper Noise

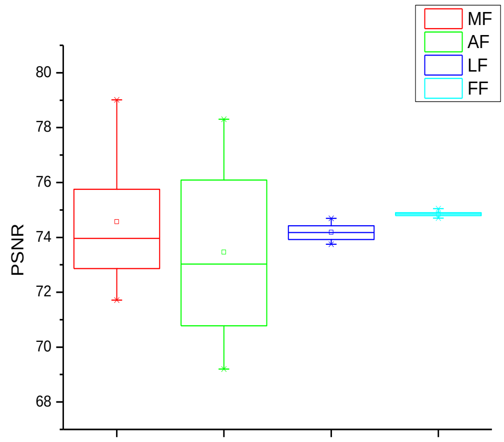


Figure 5b. Speckle noise

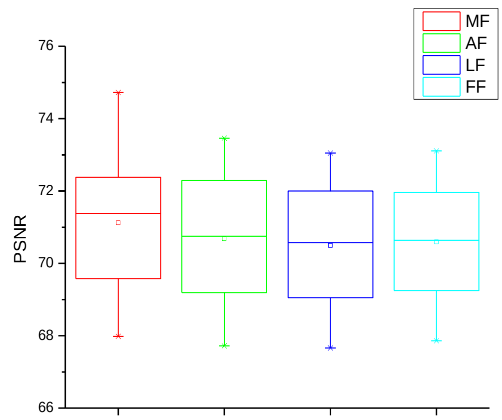


Figure 5c. Speckle noise

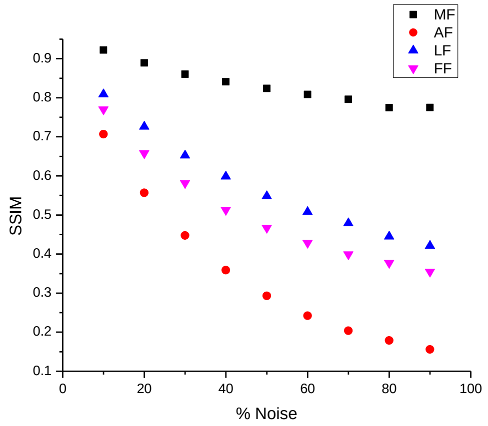


Figure 6a. Salt and pepper Noise

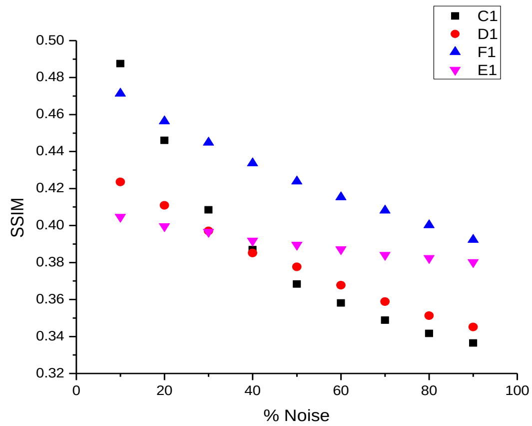


Figure 6b. Speckle noise

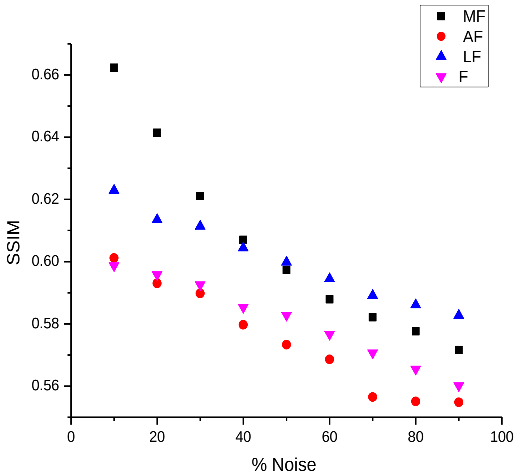


Figure 6c. Gaussian noise

Figure 6a-c SSIM value of filters

From the graphical analysis, it is found that the MF exhibits higher similarity value for all levels of noisy density. For the speckle noise removal, FF exhibits higher accuracy whereas more or less all the filters exhibits same accuracy for Gaussian noise.

IV.CONCLUSION

This work investigated the performance of four different filtering topology testedwith three different noises over three different dataset of MRI images. The Median filter exhibits high performance method as compared to other filters for salt-pepper noise de-noising.The Frost filter outperformed as compared to otherfilters for speckle noise de-noising. All the proposed filters showsappropriate performance overGaussian de-noising. Thus this work prove that the choice of filter depends upon the type noisepresent in an image. This analysis will improve the accuracy of MRI images for otherprocessing step such as segmentation and feature extraction.

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