Noise Removal In MR Images Using Non-Linear Filters

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Abstract*- Images are imitations of real world objects. Often an image is a two dimensional (2D) signal f(x,y) represent the amplitude or intensity of the image. In the Transmission of images, they are corrupted by salt and pepper noise, due to faulty communications. Salt and Pepper noise is also known as Impulse noise. The target of straining is to eliminate the compulsions so that the noise less image is fully improved with slightest signal alteration. The best-known and most commonly used nonlinear digital filters, based on order statistics are median filters, also known as Simple Median Filter (SMF). Median filters are acknowledged for their competency to eliminate impulse noise deprived of damaging the edges. Median filters are documented for their competency to confiscate impulse noise as well as preserve the boundaries. The effective confiscation of impulse often hints to images with distorted and inaccurate features. Ideally, the filtering should be applied only to corrupted pixels while leaving uncorrupted pixels intact. Applying median filter unconditionally across the entire image as practiced in the conventional schemes would inevitably alter the intensities and remove the signal details of uncorrupted pixels. Hence, a noise-detection process to categorize between virtuous pixels and the degraded pixels prior to smearing nonlinear filtering is highly desirable.*

The main aim of this work is to modify the existing median filters and implement the modified median filter for reduction of high density impulse noise (salt & pepper noise). Then evaluate the performance of the algorithm using MSE & PSNR parameters.

Keywords- MSE, PSNR, SMF, high density impulse noise, WMF, CWM, ACWM, AMF

I. INTRODUCTION

Computers are faster and more accurate than human beings in processing numerical data. However, human beings score over computers in recognition capability. The human brain is so sophisticated that we recognize objects in a few seconds, without much difficulty. We may see a friend after ten years, yet recognize him/her in spite of the change in his/her appearance as the method by which humans gather knowledge for recognition is very unique. Human beings use all the five sensory parts of the body to gather knowledge about the outside world. Among these perceptions, visual information plays a major role in understanding the surroundings. Other kinds of sensory information are obtained from hearing, taste, smell, and touch. The old Chinese proverb "A picture speaks a thousand words" rightly points out the images are very powerful tools in communication. With the advent of cheaper digital cameras and computer systems, we are witnessing a powerful digital revolution where images are being increasingly used to communicate ideas effectively [1].

We encounter images everywhere in our daily lives. We see many visual information sources such as paintings and photographs in magazines, journals, image galleries, digital libraries, newspapers, advertisement boards, television, and the internet. Images are virtually everywhere! Many of us take digital snaps of important events in our lives and preserve them as digital albums. Then through the digital album we print digital pictures and/or mail them to our friends to share our feelings of happiness and sorrow. However, images are not used merely for entertainment purposes. Doctors use medical images to diagnose problems for providing treatments. With modern technologies, it is possible to image virtually all anatomical structures, which is of immense help to doctors, in providing better treatment. Forensic imaging applications process fingerprints recognition, hand recognition, faces recognition, and irises to identify criminals. Industrial applications use imaging technology to count and analyze industrial components. Remote sensing applications use images sent by satellites to locate the minerals present in the earth. Thus, images find major applications in our everyday life.

Images are imitations of real world objects. Often an image is a two dimensional (2D) signal f(x,y) represent the amplitude or intensity of the image. For processing using digital computers, this image has to be converted to the discrete form using the process of sampling and quantization, known collectively as digitization. In image processing, the term 'image' is used to denote the image data that is sampled, quantized and readily available in a form suitable for further processing by digital computers.

This chapter describes the various aspects of image processing, the causes and the effect of noise on image.

II. PROBLEM IDENTIFICATION

To improve the interpretability or perception of information in images for human viewers, or to provide better input for other automated image processing techniques is the main focus of image enhancement. It refers to accentuation, or sharpening, of image options like boundaries, or contrast to create a graphic show a lot of helpful for show & amp; analysis. This method doesn't increase the inherent info content in image. It includes grey level & amplitude; distinction manipulation, noise reduction, edge adjusting and sharpening, filtering, interpolation and magnification, pseudo coloring, and so on. Image enhancement can be sub divided in two categories:

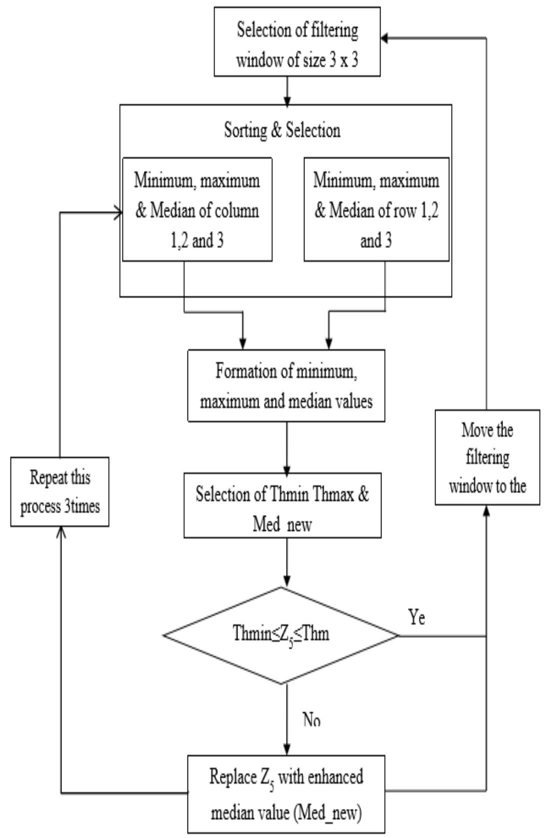
1. Spatial domain methods, which operate directly on pixels.
2. Frequency domain methods, which operate on the Fourier transform of an image.

Image Restoration: Removing or reducing the degradations that have occurred while the digital image is referred as Image Restoration. It is concerned with filtering the observed image to minimize the effect of degradations. Effectiveness of image restoration depends on the extent and accuracy of the knowledge of degradation process as well as on filter design. Image restoration differs from image enhancement in that the latter is concerned with more extraction or accentuation of image features.

The quality of such data representation is characterized by parameters such as data accuracy and precision. Data accuracy is the property of how well the pixel values of an image are able to represent the physical properties of the object that is being imaged. Data accuracy is an important parameter, as the failure to capture the actual physical properties of the image leads to the loss of vital information that can affect the quality of the application. While accuracy refers to the correctness of a measurement, precision refers to the repeatability of the measurement. In other words, repeated measurements of the physical properties of the object should give the same result. Most software use the data type “double” to maintain precision as well as accuracy.

III. PROPOSED ALGORITHM

In this chapter identifying the noise in the image and then denoising it using double threshold median filter as well as preserving edges of image.



Flow chart of proposed method for filtering window size 3x3

The simple algorithm is developed in which we perform the noise detection & noise removal process simultaneously. The smallest window size is used which preserves the fine details of image. The window of size 3x3 chooses for noise detection and noise removal. The window contains total 9 elements which are as follows: Z1, Z2, Z3, Z4, Z5, Z6, Z7, Z8, Z9. First step selects the maximum, minimum and median values of columns and rows. Second step stores these values and selects minimum threshold, maximum threshold and final median value. Third step use threshold values for noise detection and final median value for noise removal. We can divide the complete process into no. of steps as follows:

Filtering window of size 3x3

	Column 1	Column 2	Column 3
Row 1	Z_1	Z_2	Z_3
Row 2	Z_4	Z_5	Z_6
Row 3	Z_7	Z_8	Z_9

Step-1: First all columns of filtering window is selected one by one and then we find three values i.e. Maximum, Minimum and Median in each column. The mathematical expression can be shown as follow: The minimum values of rows and columns are represented as

Min (cln1) = min { Z1, Z4, Z7}
Min (cln2) = min { Z2, Z5, Z8}
Min (cln3) = min { Z3, Z6, Z9}
Min (row1) = min { Z1, Z4, Z7}
Min (row2) = min { Z2, Z5, Z8}
Min (row3) = min { Z3, Z6, Z9}

The maximum value of rows and columns are represented as

Max (cln1) = max { Z1, Z4, Z7}
Max (cln2) = max { Z2, Z5, Z8}
Max (cln3) = max { Z3, Z6, Z9}
Max (row1) = max { Z1, Z4, Z7}
Max (row2) = max { Z2, Z5, Z8}
Max (row3) = max { Z3, Z6, Z9}

The median value of the rows and columns are represented as

Med (cln1) = med { Z1, Z4, Z7}
Med (cln2) = med { Z2, Z5, Z8}
Med (cln3) = med { Z3, Z6, Z9}
Med (row1) = med { Z1, Z4, Z7}
Med (row2) = med { Z2, Z5, Z8}
Med (row3) = med { Z3, Z6, Z9}

Step-2: Now total nine values (three maximum, three minimum and three median) are there. These values will be used to calculate threshold values (maximum threshold and minimum threshold) and median value. For these calculations, three different groups of these nine elements are made.

Max_group = {Max (cln1), Max (cln2), Max (cln3) Max (row1), Max (row2), Max (row3)}

Min_group = {Min (cln1), Min (cln2), Min (cln3) Min (row1), Min (row2), Min (row3)}

Med_group = {Med (cln1), Med (cln2), Med (cln3) Med (row1), Med (row2), Med (row3)}

First max_minis calculated by choosing maximum value in min_group and min_max by choosing minimum value in max_group. Then minimum threshold is choseby choosing minimum value in max_group.

max_min = Max {Min (cln1), Min (cln2), Min (cln3) Min (row1), Min (row2), Min (row3)}

min_max = Min {Max (cln1), Max (cln2), Max (cln3) Max (row1), Max (row2), Max (row3)} median_med = Med {Med (cln1), Med (cln2), Med (cln3) Med (row1), Med (row2), Med (row3)}

Now these three values (max_min, min_max, median_med) will be furhter sorted and finally minimum threshold is obtained, maximum threshold and final median value as follows:

Thmax = max {min_max, median_med, max_min}
Thmin = min {min_max, median_med, max_min}
Final_med= med { min_max, median_med, max_min }

These two threshold values will be used for noise detection and final median will be used for noise removal.

Step-3: Now noise detection and noise removal operation will be performed using these three values i.e. Thmax, Thmin, and Med_new. The central pixel with threshold values is compared. If the central pixel is in between the Thmin and Thmax, then the pixel will be considered as noise free, then pixel will remain unchanged and window will move or slide to the next pixel. Otherwise pixel will consider as noisy and it will be replaced by median value.

If Thmin ≤*Z5*≤ Thmax
Then X5 is unchanged.
Else X5= Med_new.

Here the threshold values and median value are parallel calculated. So there is no need to perform noise detection and noise removal separately.

IV. PROCEDURE FOR ALGORITHM

The proposed modified median filter applied to the random noisy image and get the noise free image is explain step by step as follow:

Step-I: Read the image in MATLAB software otherwise read the image in whole computer.

Command of MATLAB	
Read the image in MATLAB	Read the image in System
imread ('image name. image format')	imread ('Location/image name/image format')

Step II: Select the box according to the image and applied to the modified median filter

Example: Suppose 3×3 block is select then

$$J1 = \begin{bmatrix} 61 & 68 & 54 \\ 51 & 65 & 60 \\ 60 & 62 & 49 \end{bmatrix}_{3\times3}$$

Step III: Applied modified median filter applied to this block. First selects the maximum, minimum and median values of columns and rows. Second step stores these values and selects minimum threshold, maximum threshold and final median value. Third step use threshold values for noise detection and final median value for noise removal.

The minimum values of rows and columns are represented as

Min (cln1) = min {61, 51, 60} = 51
Min (cln2) = min {68, 65, 62} = 62
Min (cln3) = min {54, 60, 49} = 49
Min (row1) = min {61, 68, 54} = 54
Min (row2) = min {51, 65, 60} = 51
Min (row3) = min {60, 62, 49} = 49

The maximum value of rows and columns are represented as

Max (cln1) = max {61, 51, 60} = 61
Max (cln2) = max {68, 65, 62} = 68
Max (cln3) = max {54, 60, 49} = 60
Max (row1) = max {61, 68, 54} = 68
Max (row2) = max {51, 65, 60} = 65
Max (row3) = max {60, 62, 49} = 62

The median value of the rows and columns are represented as

Med (cln1) = med {61, 51, 60} = 60
Med (cln2) = med {68, 65, 62} = 62
Med (cln3) = med {54, 60, 49} = 54
Med (row1) = med {61, 68, 54} = 61
Med (row2) = med {51, 65, 60} = 60
Med (row3) = med {60, 62, 49} = 60

Now total nine values (three maximum, three minimum and three median) is obtained. These values to calculate threshold values (maximum threshold and minimum threshold) and median value is used. For these calculations, we make three different groups of these nine elements.

Min_group = {Min (cln1), Min (cln2), Min (cln3) Min (row1), Min (row2), Min (row3)}
Min_group = 49

Max_group = {Max (cln1), Max (cln2), Max (cln3) Max (row1), Max (row2), Max (row3)}
Max_group = 68

Med_group = {Med (cln1), Med (cln2), Med (cln3) Med (row1), Med (row2), Med (row3)}
Med_group = 60

First calculate max_minis calculated by choosing maximum value in min_group and min_max by choosing minimum value in max_group. Then minimum threshold is chosenby choosing minimum value in max_group.

min_max = Min {Max (cln1), Max (cln2), Max (cln3) Max (row1), Max (row2), Max (row3)}
min_max = 60

max_min = Max {Min (cln1), Min (cln2), Min (cln3) Min (row1), Min (row2), Min (row3)}
max_min = 62

Now these three values (max_min, min_max, median_med) will be further sorted and finally minimum threshold is obtained, maximum threshold and final median value as follows:

Thmin = min {min_max, median_med, max_min} = 60
Thmax = max {min_max, median_med, max_min} = 62
Final_med= med { min_max, median_med, max_min } = 60
These two threshold values will be used for noise detection and final median will be used for noise removal.

Now noise detection and noise removal operation will be performed using these three values is compared i.e. Thmax, Thmin, and Med_new. If the central pixel is in between the Thmin and Thmax, then the pixel will be considered as noise free, then pixel will remain unchanged and window will move or slide to the next pixel. Otherwise pixel will consider as noisy and it will be replaced by median value.

V. RESULT ANALYSIS

Any handling connected to a picture may bring about a critical loss of data or quality. The PSNR is most normally utilized as a measure of nature of remaking of misfortune pressure codecs e.g., for picture pressure. The flag for this situation is the first information, and the clamor is the qualities presented by incautious commotion.When comparing denoising results it is used as an approximation to human visibility of reconstruction quality, therefore in some cases one denoising results may appear to be closer to the original than another methods, even though it has a lower PSNR and a higher PSNR would normally indicate that the denoising method is of higher quality. We have to be extremely careful with the range of results; it is only comparably valid when it is used to compare results from the different denoising algorithms and same content.

The PSNR value approaches as high as possible the MSE approaches to zero; these results show that a higher PSNR value provides a better image quality. At the other end of the parameter, a small change in the PSNR indicates high numerical differences between image qualities. PSNR is usually represents in terms of the logarithmic decibel.
This algorithm is mainly used for high density impulse noise because many algorithms give good results at low noise densities but very poor results at high noise densities. Using this method, we have performed image de-noising on brain image and foot image of size 256*256 and simulate their results on MATLAB. For different high noise density levels that are 50%-90%, the resultant PSNR is shown in table5.1, and we made a comparative analysis based on this peak signal to noise ratio known as PSNR of de-noised image.

$$PSNR = 10log_{10}\frac{(No\ of\ gray\ level)^2}{MSE} \quad (5.1)$$

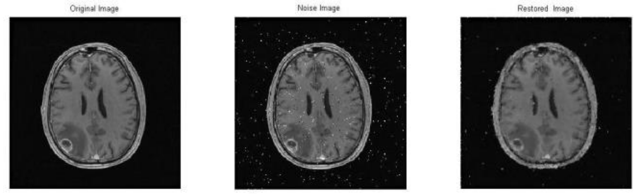
Where MSE (Mean square error), is

$$MSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\{Z(i,j)-A(i,j)\}^2}{m\times n} \quad (5.2)$$

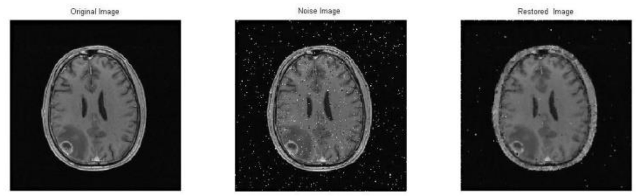
Where Z(i,j) is Original image & A(i,j) is noisy image.

De-noised MRI Images

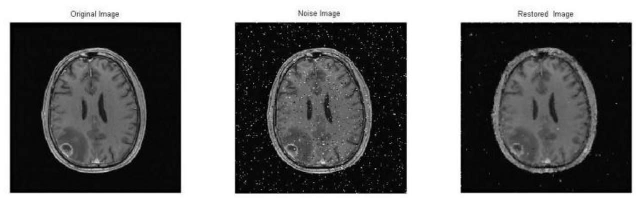
This method is tested on real brain and foot images shown in below:



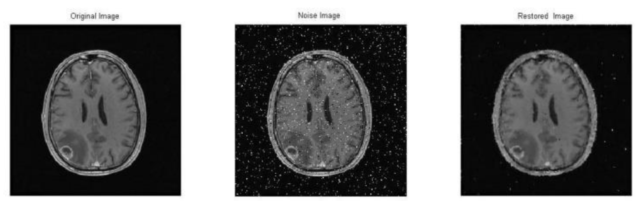
(a) 0.01 Salt & Pepper noise and restored/filtered image



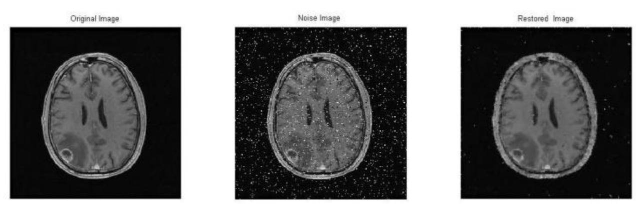
(b) 0.02 Salt & Pepper noise and restored/filtered image



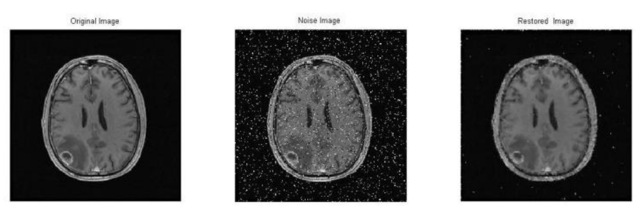
(c) 0.03 Salt & Pepper noise and restored/filtered image



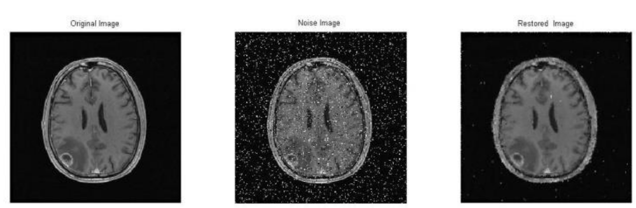
(d)0.04 Salt & Pepper noise and restored/filtered image



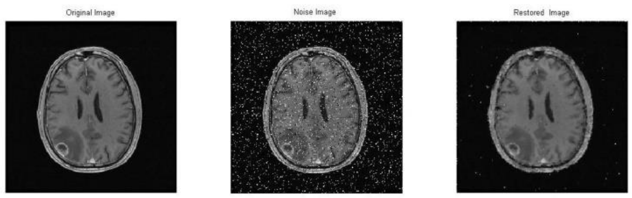
(e) 0.05 Salt & Pepper noise and restored/filtered image



(f) 0.06 Salt & Pepper noise and restored/filtered image



(g) 0.07 Salt & Pepper noise and restored/filtered image



(h) 0.08 Salt & Pepper noise and restored/filtered image

0.09 Salt & Pepper noise and restored/filtered image

Figure 5.1: Experimental Results of Proposed Method for real Brain Image

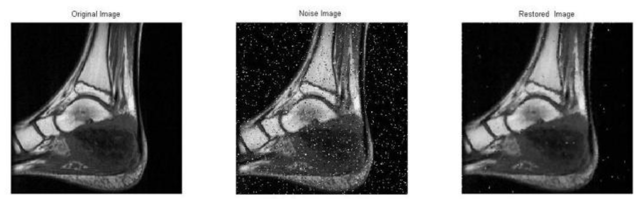
Figure 5.1 shows the noisy brain image by different density of salt & pepper noise and restored image by proposed filter. From the visual outputs, it is very clear that image de-noised by proposed method has good quality.

(a) 0.01 Salt & Pepper noise and restored/filtered image

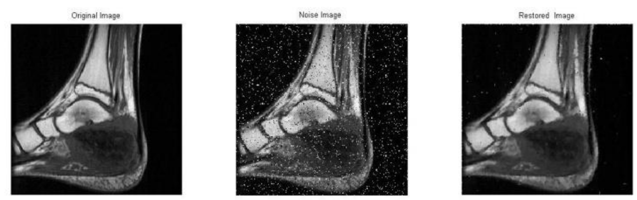
(b) 0.02 Salt & Pepper noise and restored/filtered image

(c) 0.03 Salt & Pepper noise and restored/filtered image

(d) 0.04 Salt & Pepper noise and restored/filtered image



(e) 0.05 Salt & Pepper noise and restored/filtered image



(f) 0.06 Salt & Pepper noise and restored/filtered image

(g) 0.07 Salt & Pepper noise and restored/filtered image

(h) 0.08 Salt & Pepper noise and restored/filtered image

(i) 0.09 Salt & Pepper noise and restored/filtered image

Figure 5.2: Experimental results of proposed method for real foot image

Figure 5.2 shows the noisy foot image by different density of salt & pepper noise and restored image by proposed filter. From the visual outputs, it is very clear that image de-noised by proposed method has good quality

PSNR of De-noised MRI Image

The results in the Table 5.1 clearly show that the PSNR of different method is much better at high density of salt and pepper noise. As the density of noise increasing, the response of proposed filter is becomes better in comparison of other filters.

Table: 5.1: Comparison of PSNR for two images at same noise density

Density	Brain Image	Foot Image
0.01	45.40	47.34
0.02	42.40	44.10
0.03	40.52	42.26
0.04	39.48	41.12
0.05	38.39	40.24
0.06	37.56	39.17
0.07	36.99	38.67
0.08	36.37	37.90
0.09	35.96	37.64

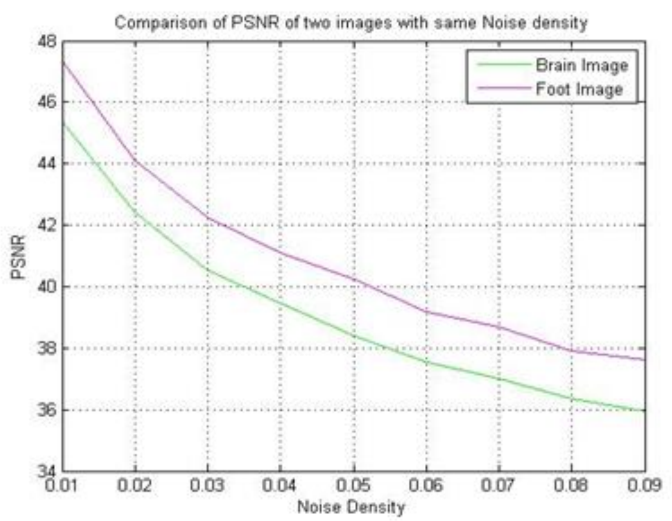


Figure 5.3: Graph for PSNR value of the different image at same density

Figure 5.3 shows the graphical illustration of the performance of proposed method discussed in this research work in term of peak signal to noise ratio (PSNR). From the above graphical representation it can be inferred that the proposed architecture gives the best performance for foot image.

MSE of De-noised MRI Image

Table 5.2 clearly shows the mean square error (MSE) of the brain and foot image. The density of the image is increase than increase the MSE of the image. Density of the image and MSE both are proportional to each other.

Table 5.2: Comparison of MSE for two images at same noise density

Density	Brain Image	Foot Image
0.01	1.87	1.19
0.02	3.73	2.57
0.03	5.76	3.86
0.04	7.31	5.01
0.05	9.40	6.15
0.06	11.38	7.86
0.07	12.97	8.87
0.08	14.96	10.53
0.09	16.48	11.87

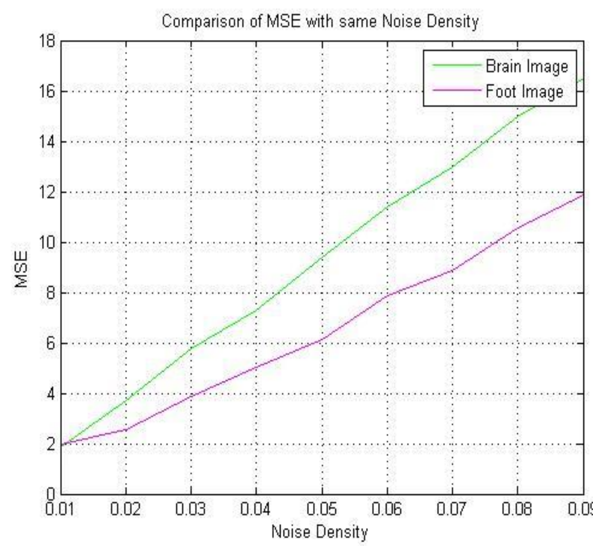


Figure 5.4: Graph for MSE value of the different image at same density

Figure 5.4 shows the graphical illustration of the performance of proposed method discussed in this research work in term mean square error (MSE). From the above graphical representation it can be inferred that the proposed architecture gives the best performance for foot image.

Result for Rician Noise Image

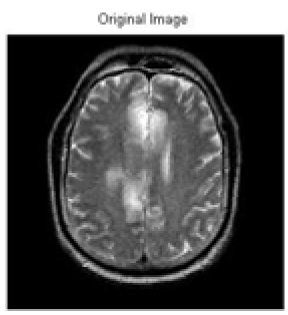
Rician noise image is also knows as Gaussian noise. Rician noise is statistical noise having a probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution.In other words, the values that the noise can take on are Gaussian-distributed.

$$P(Z) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(z-\mu)^2}{2\sigma^2}} \quad (5.3)$$

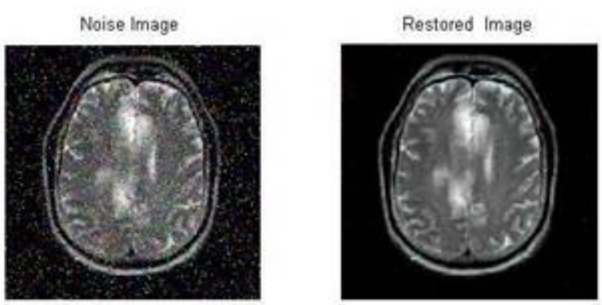
The results in the Table 5.3 clearly show that the PSNR of different method is much better at high density of salt and pepper noise. As the density of Rician noise of density 6% and restored/filtered image noise increasing, the response of proposed filter is becomes better in comparison of other filters.

Table: 5.3: Comparison of PSNR of Different Filter for Different Image

Noise Level	Priyanka et al. [1]	Proposed Modified Median Filter
0.03	29.81	42.67
0.06	26.05	39.57
0.09	23.24	38.08
0.12	20.97	36.79
0.15	19.20	35.80

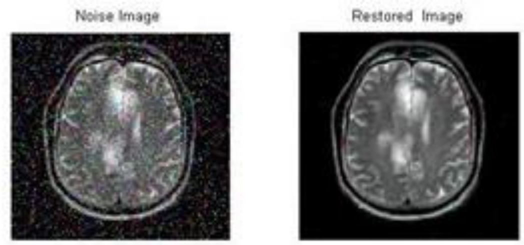


(a) Original brain image used for Rician noise

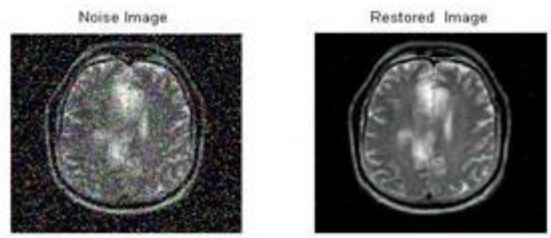


(b) Rician noise of density 3% and restored/filtered image

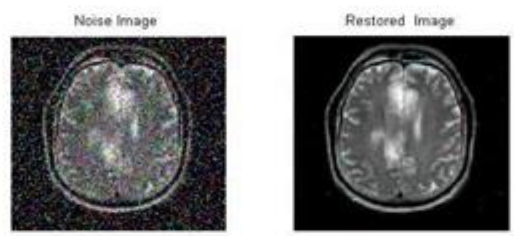
(c) Rician noise of density 6% and restored/filtered image



(d) Rician noise of density 9% and restored/filtered image



(e) Rician noise of density 12% and restored/filtered image



(f) Rician noise of density 15% and restored/filtered image

Figure 5.5: Experimental results of proposed method for different density of Rician Noise

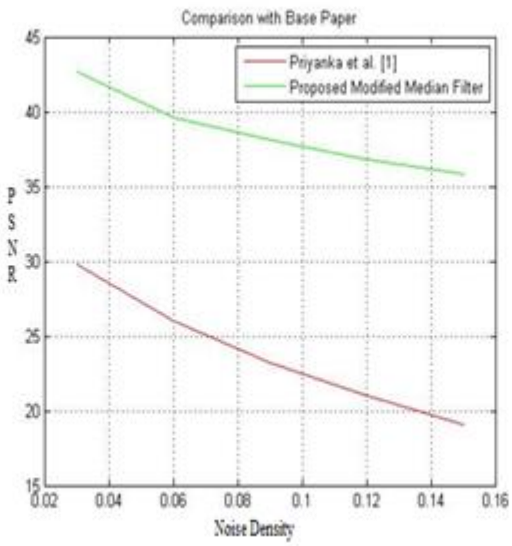


Figure 5.6: Graph for comparison of proposed method with base paper method for Rician noise

Figure 5.6 shows the graphical illustration of the performance of proposed method discussed in this research work in term of peak signal to noise ratio (PSNR). From the above graphical representation it can be inferred that the proposed architecture gives the best performance for all noise level

VI. CONCLUSION

The proposed channel has demonstrated that it is exceptionally productive for irregular esteemed motivation commotion in light of the fact that for all intents and purposes clamor is not uniform over the channel. The idea of most extreme and least limit is utilized here to distinguish both positive and negative commotion. It delivers great PSNR (Peak Signal to Noise Ratio) and little MSE (Mean Square Error) for profoundly debased pictures, particularly for over half clamor thickness. This calculation is straightforward and requires less number of estimations than different channels like CWM, TSM, SD-ROM, IMF and so forth little size of separating window gives favorable position of conservation of fine points of interest of picture. Due to its less unpredictability of count, this channel will have incredible application in the field of picture handling.The resultof images clearly indicate that the quality of de-noised image is better in visual form at that much high noise density. The proposed method improved the quality of de-noised image especially for random valued impulse noise. PSNR & MSE has been calculated for the performance analysis and result shows excellent variations in the result.

VII. FUTURE SCOPE

Based on the results of the investigations presented in this work, some suggestions for the future work in the field of Image restoration are summarized. This method can have great application in the field of communication, because large amount of noise introduced during the transmission of data. This method can be implemented using parallel processing or pipelining. With the help of parallel processing we can speed up the process and reduce execution time. Because of its easy hardware implementation, this method can replace the existing de-noising methods. It can be used in GPS system as well with some modification and can give better picture quality at high noisy environment.

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