De-noising MRI Image of High Density Different Noise using Linear and Nonlinear Threshold Filter

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Abstract. *Noise removal in Magnetic Resonance Imaging (MRI) is crucial for ensuring high-quality images, which are essential for accurate medical diagnoses and the study of anatomical structures. MRI images are often compromised by various types of noise, which can degrade image quality and obscure critical diagnostic details. In this study, a Modified Median Filter is proposed to address the challenge of de-noising MRI images. The technique improves upon traditional median filtering by adapting the filter window size based on local noise characteristics within the image, ensuring both effective noise suppression and preservation of fine anatomical structures. The filtering process is optimized using a 3x3 window to maintain image sharpness and contrast. The performance of the proposed method is evaluated using Peak Signal-to-Noise Ratio (PSNR) and contrast ratio metrics, which demonstrate significant improvements in image clarity and detail retention. The results show that the Modified Median Filter is highly effective in removing noise while preserving important image features, making it a valuable tool for enhancing the quality of MRI images in clinical settings.*

***Keywords:* -** Gaussian Noise, Median Filter, De-noising, Threshold Filter, MRI image, PSNR, medical imaging

I. INTRODUCTION

Image processing is an important area in the information industry [1]. A crucial research is how to filter noise caused by the nature, system and processing of transfers and so on. Image de-noising is one of the most famous and widely studied algorithms in image processing and computer vision. There is need of having a very good image quality required with the use of the new technologies in a various fields such as multimedia technology [2], medical image enhancement, aerospace, video systems and many others. Indeed, the acquired image is often affected by noise which may have a multiple sources such as: thermal fluctuations; quantify effects and characteristics of communication channels. It affects the original quality of the images, decreasing not only the quality of the image but also the performance of the process for which the image has been made to use [3]. The main goal is to design such methods, which can smoothly recover a degraded image without altering its edges, losing significant information and producing reliable results [4]. Magnetic Resonance Imaging (MRI) has become one of the most essential non-invasive imaging modalities in medical diagnostics, providing detailed images of soft tissues and organs. However, the inherent sensitivity of MRI to various types of noise—such as Gaussian, Salt-and-Pepper, and Rician noise—can severely degrade image quality [5]. This noise, which arises from a variety of sources including the environment, machine electronics, and patient movement, reduces the clarity of images and hampers accurate diagnosis [6]. De-noising MRI images [7], therefore, is crucial to improve image quality and enhance diagnostic precision. Conventional de-noising techniques have been employed with mixed success, primarily due to the complexity of noise patterns in high-density settings [8]. While linear filters such as Gaussian smoothing are effective at removing uniform noise, they often blur fine details, leading to a loss of critical diagnostic information [9]. On the other hand, nonlinear filtering techniques, including median filters and wavelet-based methods, preserve image edges and fine structures but may introduce artifacts or fail in cases of extreme noise density [10]. This study focuses on the application of both linear and nonlinear threshold filtering approaches to de-noise MRI images affected by various types of high-density noise. By employing a combination of these techniques, the aim is to balance noise reduction and image detail preservation [11]. Specifically, the use of threshold-based filtering offers a flexible approach to selectively suppress noise while maintaining structural integrity in the image [12]. This hybrid approach is expected to outperform traditional methods by providing clearer and more accurate MRI images even in the presence of complex noise conditions [13]. In this paper, we explore the effectiveness of linear and nonlinear threshold filters in reducing high-density noise in MRI images. The results demonstrate the advantages of combining both filtering approaches to achieve significant noise suppression without compromising image quality, ultimately aiding in more precise medical diagnosis.

II. Literature Review

The research on MRI image denoising techniques explores various filters and hybrid approaches to effectively remove noise while preserving image details. Commonly addressed noise types include Gaussian, Salt & Pepper, and Rician noise. Techniques such as median filters, adaptive filters, non-local means, and hybrid models like MCR (concatenation and residual deep learning) show improved denoising performance, evaluated using metrics like PSNR, SSIM, and MSE. Hybrid approaches, combining methods like Wiener filtering with texture analysis or bio-inspired algorithms, consistently outperform traditional filters, offering higher noise reduction and better image quality. Recent advancements in wavelet-based filters, CNNs, and fuzzy logic-based methods highlight the ongoing effort to enhance denoising efficiency for medical imaging applications.

Table 1: Summary of recent research on MRI image denoising techniques

Reference	Filters/Methods Used	Noise Type	Evaluation Metrics	Key Findings
Anitha S et al. [1]	Median filter, Gaussian filter	MRI brain and spinal cord images	RMSE, SNR, PSNR	Proposed a modified median filter; performance evaluated against other filters, focusing on noise removal without artifacts.
Ting Zhao [2]	Linear, Nonlinear, Frequency domain, Adaptive filters	Biomedical image denoising	Challenges, Filter selection, Application fields	Explored denoising techniques in biomedical imaging, emphasizing the balance between noise reduction and image detail preservation.
Raniya	Non-Local	Salt & Pepper	PSNR,	Adaptive median filter outperformed other

Ashraf et al. [3]	Means, Median, Adaptive Median filter	noise in MRI images	SSIM	filters for high PSNR and SSIM values at varying noise densities.
Cik Siti Khadijah Abdulah et al. [4]	General digital image denoising methods	Noisy images (general)	Image quality improvements	Reviewed image denoising techniques and their impact on digital image processing accuracy, sensitivity, and specificity.
Kazim Ali et al. [5]	MCR method (Concatenation + Residual DL)	Salt & Pepper, Gaussian noise	SSIM, PSNR, MSE	MCR method outperformed Median and Wiener filters, with higher PSNR and SSIM scores in MRI denoising.
Rajesh M.N et al. [6]	Hybrid approach (Wiener + Median filtering)	Gaussian, Rician noise	PSNR, MSE, SSIM	Proposed hybrid model performed better than other filters, particularly in Gaussian and Rician noise denoising.
Divya Gautam et al. [7]	GDBF + HCPSO algorithm	Medical image denoising (various noises)	PSNR, SSIM, FSIM	Hybrid strategy showed superior performance over traditional bio-inspired algorithms like PSO and CS, offering high PSNR and SSIM.
Ambika Annavarapu et al. [8]	Hybrid preprocessing algorithm (R_O_F, R_L, Block Matching 3D)	Gaussian noise	Performance analysis on datasets	Outperformed existing methods in terms of noise reduction and data reliability for X-ray, MRI, and CT images.
Hazique Aetesam et al. [9]	Various filtering and optimization methods	Gaussian-impulse noise	Experimental analysis on imaging domains	Categorized techniques based on noise type; analyzed filtering-based, optimization-based, and learning-based approaches for Gaussian-impulse noise.

III. Proposed Methodology

In this chapter identifying the noise in the image and then de-noising it using double threshold median filter as well as preserving edges of image. We have developed the simple algorithm in which we perform the noise detection & noise removal process simultaneously. We use the smallest window size 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.

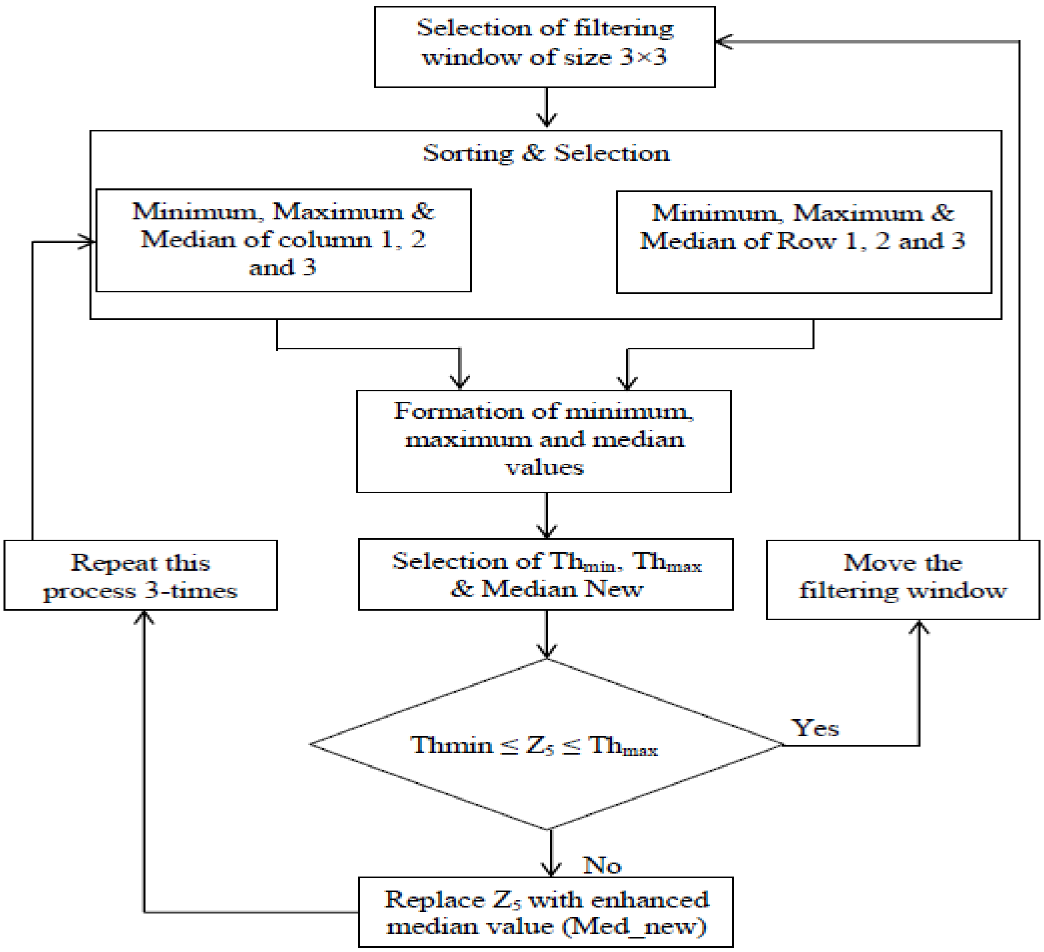

Figure: 1: Flow chart of proposed method for filtering window size 3x3

The classical modified median filter replaces the central pixel in a window with the median of the pixels into this window is shown in figure 1. The modified median is the value of the pixel that occupies the central position when arrange the window pixels in ascending order. The application of the modified median filter can be made directly over the noisy image or in a recursive proposition that uses the previously replaced values into the sliding window.

The proposed modified median filter applied to the random noisy image and get the noise free image is explained 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')

IV. Experimental Results & Discussion

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 scale.

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, Head image, Heart image of size 256x256 and simulate their results on MATLAB 2012.

MRI Brain Image

The MATLAB language is a high-level language with control flow statements, functions, data structures, input/output, and object-oriented programming features. The available libraries are vast collection of computational algorithms from basic functions such as arithmetic and trigonometric functions to complex functions such as matrix operations and Fourier transforms.

This method is tested on MRI Brain image is shown in below. Clearly that the figure 2 (a) show the original image of the Brain image. Figure 2 (b) shows the resize of original image, Figure 2 (c) shows the salt & pepper noise, Figure 2 (d) shows the restored image.

The results in the table 2 clearly show that the NAE, MSE, RMSE, SNR, PSNR and UIQI at different high density of Salt and Pepper noise are presented. As the density of noise increasing, the response of proposed algorithm is becomes decrease quality.

Table: 2: Comparison of different parameter with Different salt and Pepper Noise Density for Brain Image

Noise Density (J/K)	NAE	MSE	RMSE	SNR	PSNR	UIQI
0.01	0.01	0.09	0.30	11.78	58.53	0.003
0.02	0.02	0.19	0.43	11.18	55.37	0.006
0.03	0.03	0.29	0.53	10.83	53.52	0.004
0.04	0.04	0.39	0.62	10.59	52.22	0.0013
0.05	0.06	0.51	0.72	10.40	51.01	0.001
0.06	0.07	0.62	0.79	10.25	50.18	0.002
0.07	0.09	0.74	0.86	10.14	49.46	0.002
0.08	0.10	0.85	0.92	10.03	48.82	0.0027
0.09	0.11	0.94	0.97	9.92	48.39	0.0030

Figure 3 shows the graphical illustration of the performance of different Salt & Pepper noise density with MRI brain image discussed in this research work in term of different parameters i.e. NAE, MSE and RMSE.

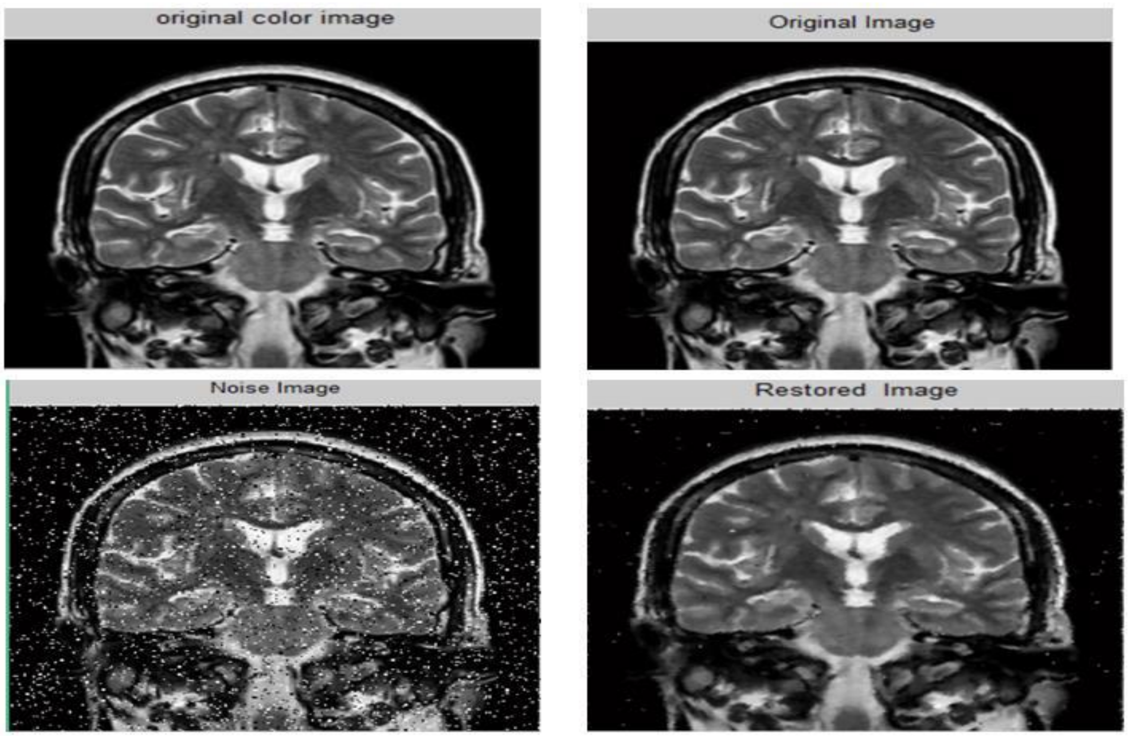

Figure 2: Experiment Result for MRI Brain Image with Salt and Pepper Noise

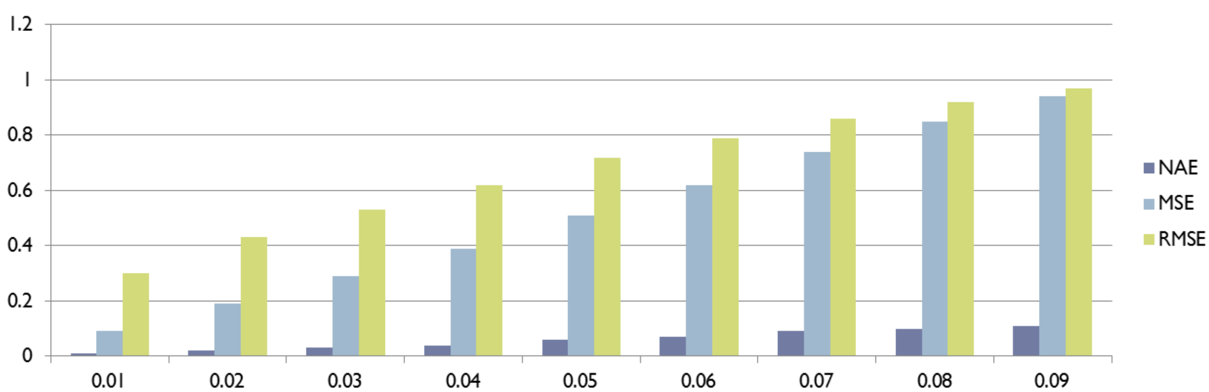

Figure 3: Bar Graph of the Error for Different Salt & Pepper Noise Density

Figure 4 shows the graphical illustration of the performance of different Salt & Pepper noise density with MRI brain image discussed in this research work in term of different parameters UIQI.

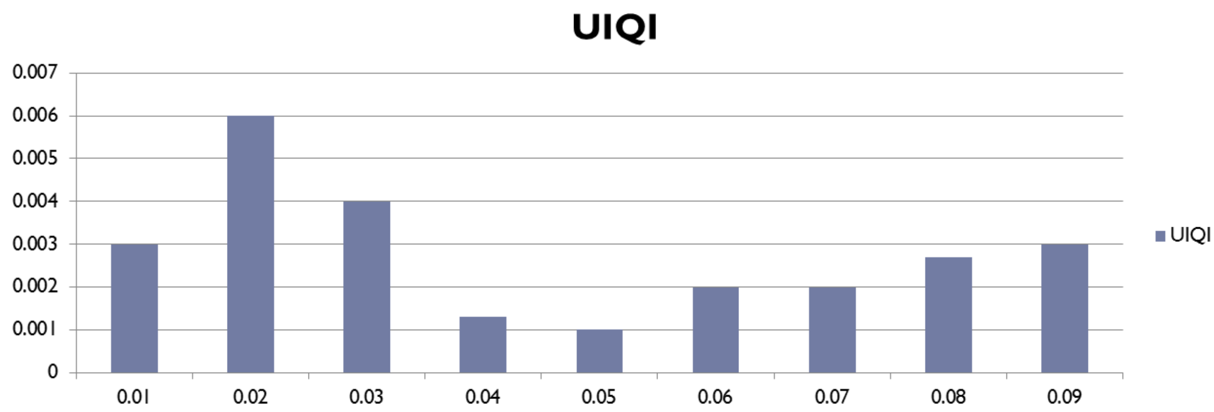

Figure 4: Bar Graph of the Quality for Different Salt & Pepper Noise Density

Figure 5 shows the graphical illustration of the performance of different Salt & Pepper noise density with MRI brain image discussed in this research work in term of different parameters i.e. SNR and PSNR.

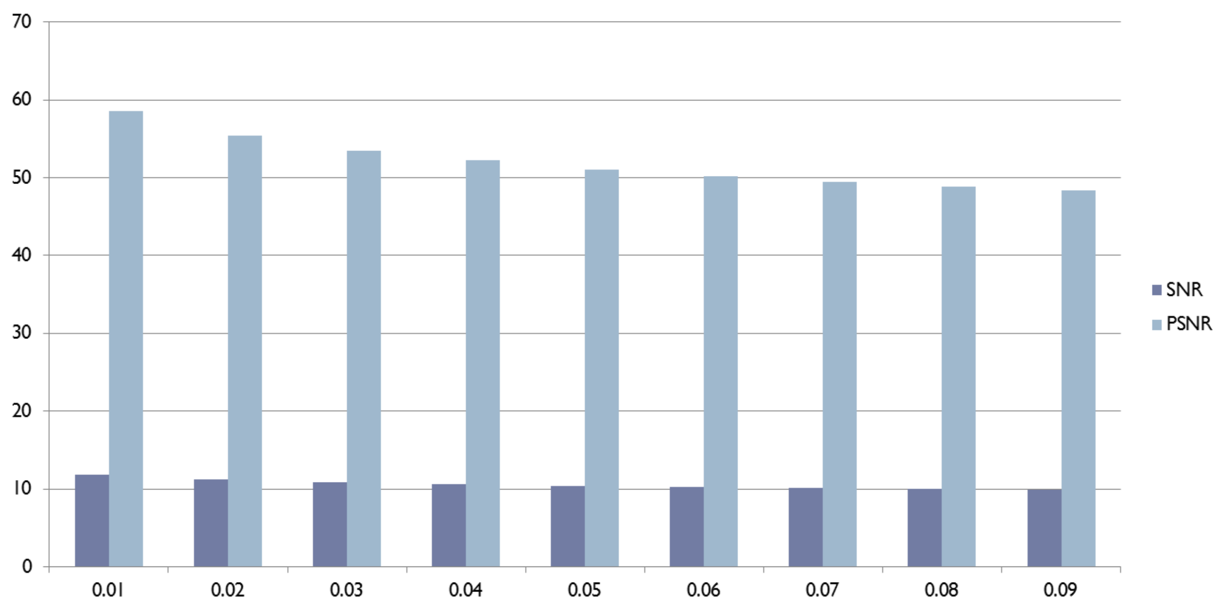

Figure 5: Bar Graph of the Signal for Different Salt & Pepper Noise Density

The results in the table 3 clearly show that the NAE, MSE, RMSE, SNR, PSNR and UIQI at different high density of Gaussian noise are presented. As the density of noise increasing, the response of proposed algorithm is becomes decrease quality.

Table 3: Comparison of different parameter with Different Gaussian Noise Density for Brain Image

Noise Density (J/K)	NAE	MSE	RMSE	SNR	PSNR	UIQI
0.01	0.01	0.16	0.40	11.75	55.97	0.003
0.02	0.04	0.37	0.61	11.18	52.40	0.006
0.03	0.07	0.63	0.79	10.88	50.16	0.009
0.04	0.11	0.82	0.91	10.68	48.97	0.0013
0.05	0.14	1.89	1.04	10.51	47.78	0.0016
0.06	0.19	1.33	1.15	10.39	46.92	0.002
0.07	0.23	1.54	1.24	10.29	46.26	0.0023
0.08	0.27	1.78	1.33	10.21	45.65	0.0026
0.09	0.32	2.02	1.42	10.13	45.10	0.0029

Figure 6 shows the graphical illustration of the performance of different Gaussian noise density with MRI brain image discussed in this research work in term of different parameters i.e. NAE, MSE and RMSE.

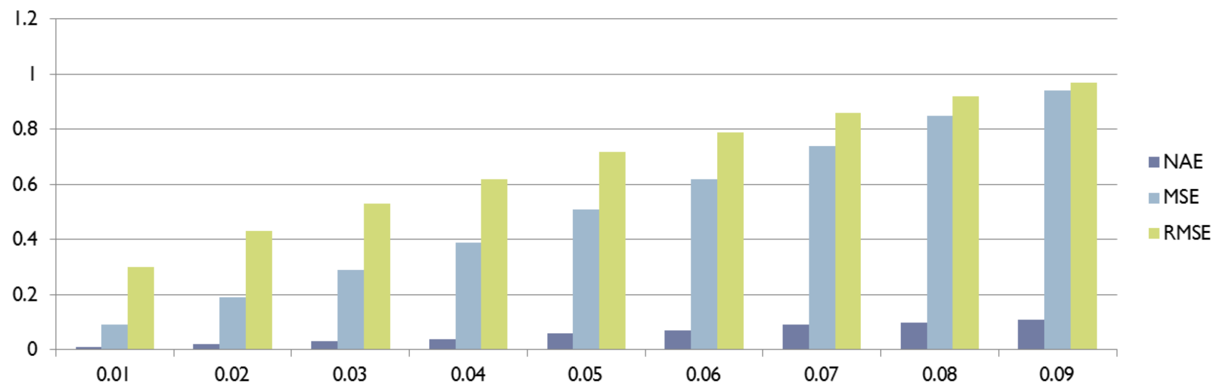

Figure 6: Bar Graph of the Error for Different Gaussian Noise Density

Figure 7 shows the graphical illustration of the performance of different Gaussian noise density with MRI brain image discussed in this research work in term of different parameters UIQI.

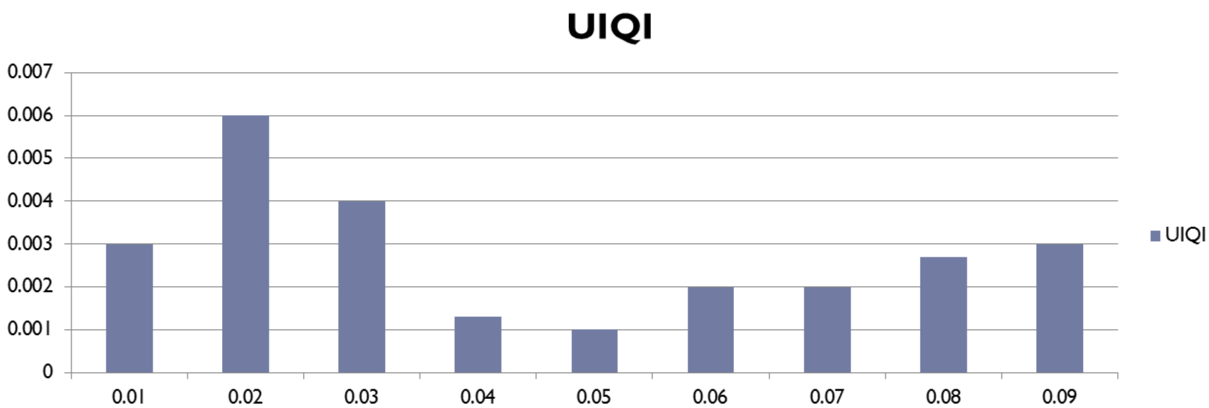

Figure 7: Bar Graph of the Quality for Different Gaussian Noise Density

Figure 8 shows the graphical illustration of the performance of different Gaussain noise density with MRI brain image discussed in this research work in term of different parameters i.e. SNR and PSNR.

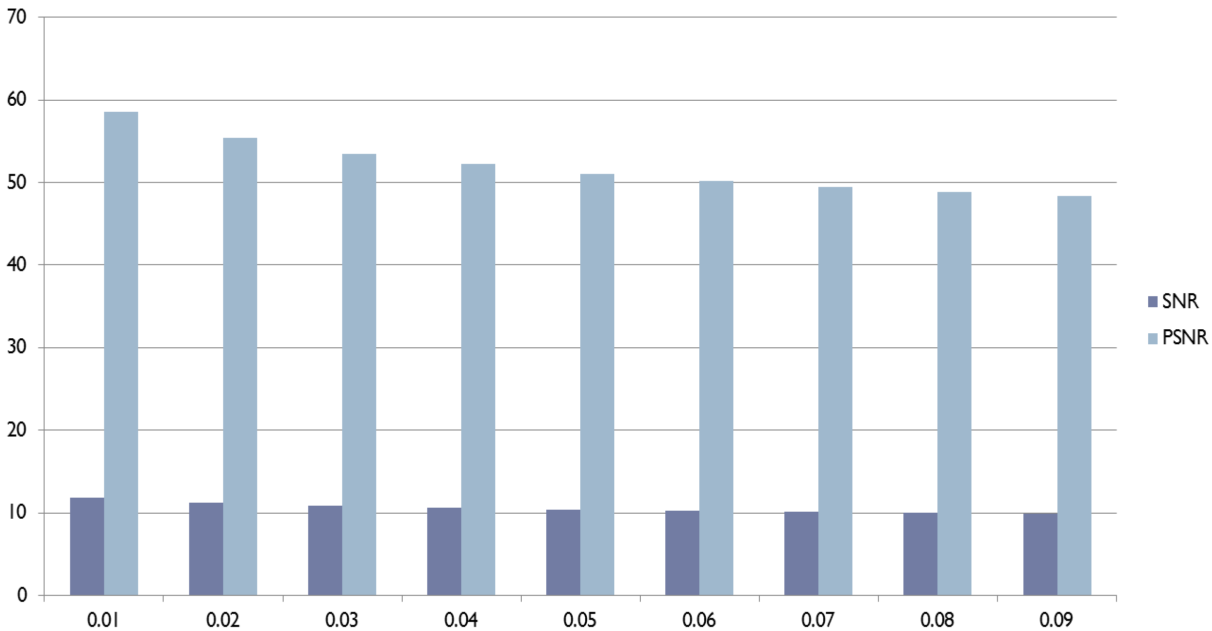

Figure 8: Bar Graph of the Signal for Different Gaussian Noise Density

Comparison result of previous and proposed algorithm is shown in table 4. The results in the Table 4 clearly show that the SNR, PSNR and RMSE of proposed algorithm is best performance compared to previous algorithm.

Table 4: Comparison result of previous and proposed algorithm

Method	Image	SNR (dB)	PSNR (dB)	RMSE
Previous Algorithm	MRI Brain Image	3.81	43.67	4.28
Proposed Algorithm		9.92	48.39	0.97

Figure 9 shows the graphical illustration of the performance of previous algorithm and proposed algorithm in term of SNR and PSNR. It is clearly that the proposed algorithm is best performance compared to previous algorithm.

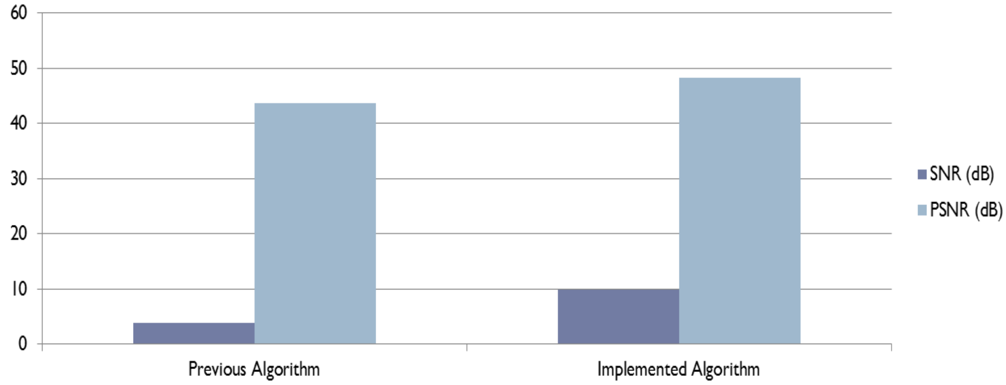

Figure 9: Bar Graph of the Previous and Proposed Algorithm for SNR & PSNR

V. Conclusions and Future Scopes

In this paper, we proposed a Modified Median Filter for de-noising MRI images, with a focus on improving image quality while preserving critical anatomical details. By adapting the filter window size based on local noise characteristics, the technique effectively reduces noise without compromising image sharpness. The performance of the filter was assessed using PSNR and contrast ratio metrics, both of which showed marked improvements compared to traditional median filtering techniques. The proposed method demonstrated superior noise suppression, particularly in noisy MRI images, while maintaining the clarity of important structural details such as edges and textures. This makes it a highly effective tool in medical imaging, where image quality is crucial for accurate diagnosis. The purpose of image de-noising is to process an image in such a way that the resulting output is clearer than the original. Salt and Pepper noise, or impulse noise, often occurs due to random bit errors in communication channels. This high-density noise can be effectively removed using the median filter, which is also beneficial in preserving edges while reducing random noise. In a median filter, a window slides across the image, and the median intensity value of the pixels within the window becomes the output intensity for that pixel. Due to its predictability and effectiveness, this method has wide applications in the field of image processing. The results clearly indicate that the quality of de-noised images is significantly improved, particularly in visually assessing images affected by high noise density. The proposed method enhanced the quality of de-noised images, especially for random-valued impulse noise. PSNR and MSE were calculated for performance analysis, and the results showed significant improvements in both metrics. This work can be further extended to denoise other types of images, such as RGB, Indexed, and Binary images, opening new avenues for broader applications in image processing and medical diagnostics.

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