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Enhanced Adaptive Threshold Median Filter For Medical Image Filtering

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ABSTRACT

In the field of medical image processing, mitigating the impact of noise is of paramount importance. Conventional median filters primarily target the elimination of medical image noise occurring as a single layer, characterized by a constant level of noise gray value. However, these filters encounter challenges when faced with images corrupted by noise that extends beyond a single layer. This study presents the Enhanced Adaptive Threshold Median Filter (EATMF) as a solution to address the aforementioned challenge. The proposed filter combines the Adaptive Median Filter (AMF) with thresholds (ATMF) and incorporates a Laplacian filter. By introducing changes in the thresholds, the EATMF achieves a balance between effectively removing both low and high density noise while preserving image quality. A comparative analysis between the EATMF and the ATMF is presented, accompanied by visual examples that showcase the performance of the newly introduced filter. The results demonstrate that the EATMF outperforms the ATMF in terms of Peak Signal-to-Noise Ratio (PSNR), indicating its superior noise reduction capabilities. This study highlights the significance of the EATMF in medical image processing, particularly in scenarios where images are corrupted by multi-layer noise. The proposed filter offers an enhanced approach to noise reduction, contributing to improved image quality and accuracy in medical diagnostics and analysis.

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INTRODUCTION

The image enhancement technique is to make the digital picture more appealing to our eyes, for example, making the images smooth or sharp. This is an important topic in digital image processing. It can help humans and computer vision algorithms obtaining accurate information from the enhanced images. The visual quality and certain image properties, such as brightness, contrast, signal-to-noise ratio, resolution, edge sharpness, and color accuracy were improved through the enhancement process. Recently, many image enhancement methods have been developed based on various digital image processing techniques and applications (Mustafa and Abdul Kader, 2018). Contrast is instrumental for visual processing and understanding of the information content within images in various settings. Therefore, computational methods for contrast enhancement (CE) are frequently used to improve the visibility of images. Among the existing CE methods, histogram transform-based algorithms are popular due to their computational efficiency (Stimper et al., 2019).
Image enhancement is the process of improving the quality of images in order to make them more suitable for visualization and analysis (Gazal et al., 2020). This is an important step in many fields, including military, medical, satellite, microbiology, and digital photography. During the image acquisition process, it is common for images to be affected by noise, overexposure, poor contrast, or blurry edges(Adedokun et al.,

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2019). Image enhancement techniques can be used to address these issues and improve the quality of the images. In the medical field, image enhancement is often used to improve the clarity of scans such as MRI, CT, and X-ray. Poor image quality can lead to an inadequate or inaccurate interpretation of the images, so image enhancement is an important step in ensuring that the images are useful for diagnosis and treatment planning (Attar *et al.*, 2018).

There are many techniques available for removing noise from images in order to improve their quality. These techniques can be divided into two categories: linear and nonlinear models. Linear models are generally fast at removing noise, but may not be able to preserve the details of the image. Nonlinear models are generally better at preserving image details, but may take longer to process. The choice of which technique to use may depend on the specific characteristics of the image and the desired trade-off between speed and detail preservation (Al-Hatmi and Yousif, 2017).

In addition to the ability to completely remove noise, a good denoising algorithm should also meet several other requirements in order to produce satisfactory results (Momoh et al., 2021). One important consideration is the preservation of edges in the image. It is important for the edges to be preserved and optimised during the denoising process in order to maintain the integrity and clarity of the image. Denoising algorithms that do not adequately preserve edges may produce results that are blurry or otherwise compromised (Mohd and George, 2020). The purpose of image enhancement is to extrude the important details hidden in the image and to increase the contrast of the image with less dynamic range (Momoh et al., 2019). Several methods are available to enhance image quality, some of them working on the spatial domain and some on the frequency domain (dubey, 2021).

RELATED METHODS

Kumar and Nachamai (2017) used different types of image filter which ranges from Weiner filter, Gaussian filter, and Median filter in denoising speckle noise, gaussian noise and poisson noise. The result of the individual filter was evaluated base on image size, histogram and image clarity. Each filter can only perform better on the type of noise it can denoise. However, the evaluation method was limited to qualitative method and the capability of each filter cannot handle mixed noise.

Roy *et al*. (2017) propose a new image pre-processing technique for enhancing digital image using modified Cuckoo search and some morphological operation. The Cuckoo search algorithm was modified using McCuttoch's method for levy flight generation and then applied it in tunning the image intensity parameter during morphological operation. Furthermore, the result obtained with enhanced Cuckoo search optimisation algorithm with dilation outperform both enhanced Cuckoo search algorithm and traditional Cuckoo search algorithm base on PSNR value.

Prabu *et al*. (2019) Design a cognitive image filter for suppression of noise level in medical images using fuzzy logic approach. The applied method starts with an experiment of adding noise to an image and converting the image to gray scale and at the same time measuring the PSNR value of the image. The PSNR of the noisy image is compared with an already existing PSNR threshold value so as to select an appropriate filter base on a design fuzzy logic rule for denoising the image.

Anoop and Bipin (2019) used an Enhanced Grasshopper Optimisation Algorithm (EGOA) in denoising MRI images with Bilateral Filter (BF). The EGOA search for the optimum window size, weight of spatial and intensity parameter in BF. The approach of using BF was also extended to another optimisation algorithm (BF with PSO, BF with GA and BF with GOA). The result obtained shows that BF with EGOA perform higher when compared with other extended BF algorithm in terms of PSNR, MSE, SSI and accuracy on MRI images. However, the approach was only limited to MRI medical image.

Baron and Lenin (2019) applied Firefly Algorithm in denoising medical images using Hybrid filter. The hybrid filter comprises of both anisotropic filter, Kalman filter and kirsch filter. To achieve proper denoising, the output from the hybrid filter is send to Support Vector Machine (SVM), which produce the hybrid image with less blur. The anisotropic filter serves as an extension of Gaussian filter to smoothing the image, the Kalman filter further improve smoothing while giving assessment of

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parameter of interest and lastly the Kirsch filter improve the edges in the image. The technique was only applied to racian noise.

Bania and Halder (2020) applied adaptive trimmed media filter for the detection and removal of impulse noise from mammogram images using MIAS database. The approach used an automatic switching mechanism for updating certain Window of Interest (WoI). In their approach, if the number of noisy pixels is more than non-noisy pixels, the window will move from (3X3) to (5x5) or from ((3X3) to (7x7). The switch depends on the amount of noise present in an image, below 48 % switch from (3X3) to (5x5) and above 48% switch from (3X3) to (7x7).

Mohd and George (2020) carried out a review on medical image denoising algorithm. According to the authors, different denoising filters can be categories into spatial domain filters, transform domain filters and hybrid filters. The spatial domain filters have the advantages of low computational complexity but with limitations of blurs in the image, poor edges and loss of resolution. The transform domain filters and hybrid filters have good edge preservation but with limitations of high computational complexity, tendency to introduce artifacts, required prior knowledge of the noise and the computational complexity also increase with dimensionality. Thus, a good denoising technique requires a reduced computational complexity, good edge preservation and nonappearance of artifacts so as to provide a spontaneous result.

Adaptive Threshold median Filter

The adaptive median filter as an improved version of median filter , also remove noise in an image and also maintain edge information. furthermore with increase in noise density, the filter is output is not satifactory (Yu *et al*., 2016).

In the Adaptive Threshold Median Filter, in the polluted region, the difference in the grey value between noise pixels and other pixels in the window is higher. In the unpolluted area, the difference in the gray value between noise pixels and other pixels in the window is lower. With this, a variable threshold with the change of the template window is adopted.

For size $M \times N$ of an image, let S_{xy} be a filter window of a true image at pixel location (x, y), $f(x, y)$ is the gray level at pixel location (x, y), S_{max} be the largest filter window, f_{min} be the minimum gray value, f_{max} be the maximum gray value, f_{med} be the median of the filter window.

Compute the mean and standard deviation of the template window with the exception of the cetre pixel according to equation (1) and (2).

$$f_{ave} = \sum_{i=1}^{n} \frac{f(x,y)}{n} \qquad (1)$$

$$f_{var} = \sqrt{\sum_{i=1}^{n} \frac{(f(x,y)-f_{ave})^2}{n}} \qquad (2)$$

Subtract the center pixel from the other pixel in the template window and take it absolute value $|\Delta f(i)|, i = 1,2, \dots n$

Compute F_1 and F_2 according to equation (3) and (4).

$$F_1 = \frac{1}{n} \sum_{i=1}^{n} |\Delta f(i)| \qquad (3)$$

$$F_2 = f_{max} - f_{min2} \qquad (4)$$

where f_{min2} is the second lowest minimum gray value

Compute the threshold T as shown in equation (5)

$$T = (F_1 + F_2) \times \frac{f_{ave}}{f_{ave} + f_{var}} \qquad (5)$$

(Yu *et al*., 2016)

Different filters have been applied in denoising medical images which ranges from linear and non-linear filters. Furthermore, some of these filters only filter only one type of noise and cannot be applied in filtering multiple noise or noise at high density. Filters that can also filter noise at the range of high density, usually experience issues of image blur and poor edges. To this extend, there is need to applied an improve filters that will provide such solution

Enhanced Adaptive Threshold Median filter

In this stage, the acquired noisy image is filtered using the traditional ATMF and EATMF. The ATMF filtering process is disscussed in section 2.8, and the EATMF is combination of ATMF and enhanced Laplacian image filter. Furthermore, the Laplacian filter is obtained from the x and y direction using the following equation (6) to equation (7).

$$\frac{d^2 f}{dx^2} = f(x+1, y) + f(x-1, y) - 2f(x, y) \qquad (6)$$

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$\frac{d^2f}{dy^2} = f(x, y+1) + F(x, y-1) - 2f(x,y)$ (7)

The Laplacian is obtained by combining the following equations:

$$\nabla^2 f = \frac{d^2f}{dx^2} + \frac{d^2f}{dy^2} \quad (8)$$

The representation of the equation in matrix form is given in equation (8) and equation (9)

$$L = \begin{bmatrix} (x-1, y+1) & (x, y+1) & (x+1, y+1) \\ (x-1, y) & (x, y) & (x+1, y) \\ (x-1, y-1) & (x, y-1) & (x+1, y-1) \end{bmatrix} \quad (8)$$

$$L = \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad (9)$$

$$L_1 = (L)convo(P) \quad (10)$$

The ATMF, the dynamic threshold and the modified Laplacian filter combined to form the EATMF using equation (10).

$$L_2 = \left(\frac{L_1}{\tanh(N)}\right) + N^2 + \sin(N^5) \quad (10)$$

where L_1 is the resultant effect of applying the laplacian filter to ATMF, N is an odd number ranging from 1 to 15. The algorithm is as shown in Figure 1.

	Enhanced Adaptive Threshold Median Filter Algorithm
Step 1	*Set inintial filter window size* $w = 3$
Step 2	*Input Noisy image*
Sep 3	*Compute minimum value* f_{min} *and maximum value* f_{max} *of current window pixels*
	Compute the threshold according to equation 5
	If $f_{max} - f_{min} > T$
	Move to Step 4
	Else move to next pixel and go to Step 1
Step 4	*Find all the pixel value between* f_{min} *and* f_{max}
	Let n be the number of finding all the pixel values
	If $n \geq w$,
	Compute the median of these pixels
	If $n < w$,
	Increase the window size by 2 and go to step 1
Step 5	*If the current pixel* $f(x,y) = f_{max} \| f(x,y) = f_{min}$
	Consider as corrupted pixels and replaced by f_{med}
	Ortherwise it is retained and move to step 1
Step 6	***Apply the Laplacian filter operation base on*** L_1 ***using equation (9)***
	Compute the final image as L_2 ***using equation (10)***

Figure 1: EATMF Algorithm

RESULTS AND DISCUSSION

The table 1 show the PSNR values for ATMF and EATMF at various noise level from 20% to 100% of Gaussian noise with the step size of 20 intervals. The obtained results indicated that the PSNR value of EATMF obtained a higher accuracy when compared with that of ATMF. The image output of both filters and the noise histogram level were shown in figure 2 to 6.

Table 1: PSNR Results Level for Gaussian Noise

% Noise Level	PSNR ATMF	PSNR EATMF
20	12.9619	18.3861
40	7.7753	11.6130
60	4.6804	7.2945
80	2.8609	4.9301
100	2.2121	4.1127

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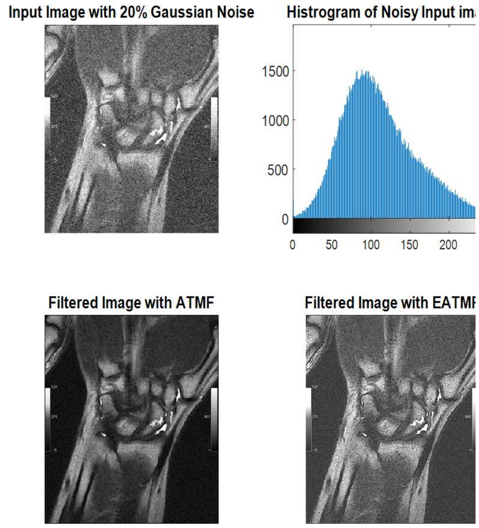

Figure 2: WRIX image with 20% Gaussian Noise

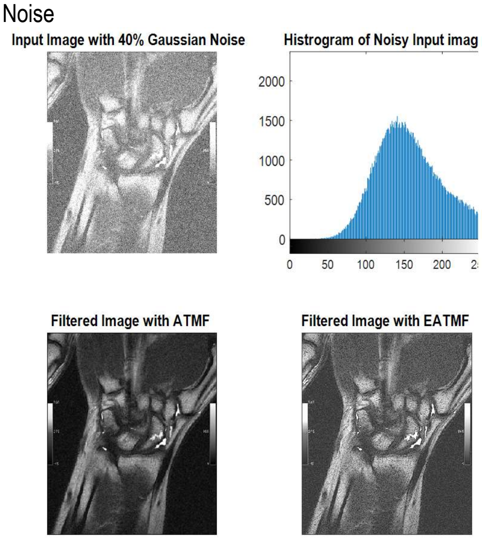

Figure 3: WRIX image with 40% Gaussian Noise

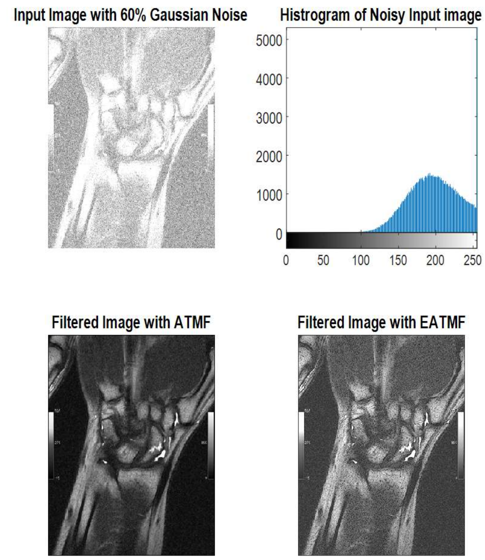

Figure 4: WRIX image with 60% Gaussian Noise

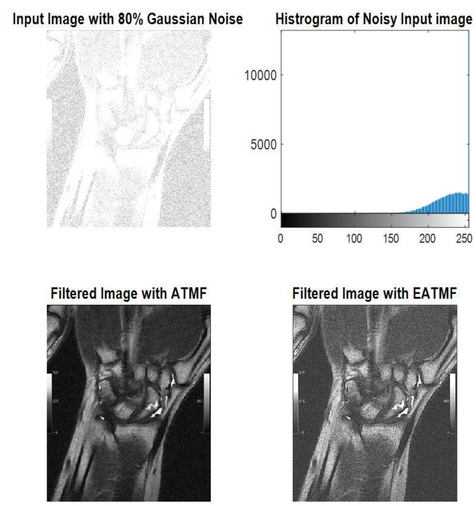

Figure 5: WRIX image with 80% Gaussian Noise

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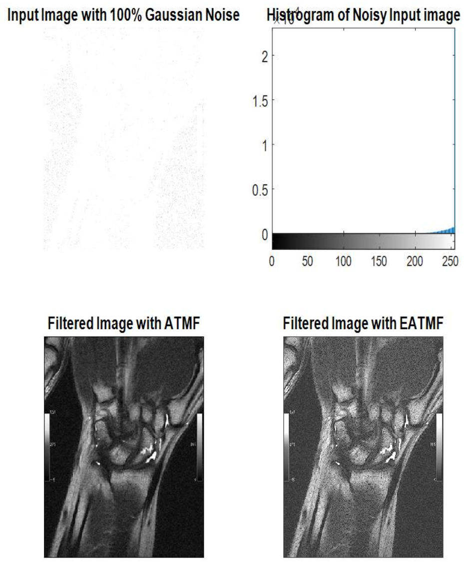

Figure 6: WRIX image with 100% Gaussian Noise

The table 2 provides the PSNR values for ATMF and EATMF at different noise level from 20% to 100% of Salt and Pepper noise with the step size of 20 intervals. The obtained results indicated that the PSNR value of EATMF obtained a higher performance when compared with that of ATMF. The image output of both filters and the noise histogram level were shown in figure 7 to 11 respectively.

Table 2: PSNR Results Level for Salt and Pepper Noise

% Noise Level	**PSNR ATMF**	**PSNR EATMF**
20	10.3924	10.6798
40	7.6336	8.2595
60	5.8809	6.8434
80	4.6151	5.7591
100	3.6457	4.9069

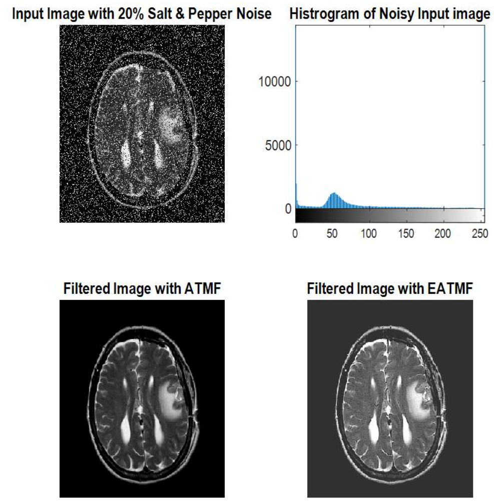

Figure 7: BRAINIX image with 20% Salt & Pepper Noise

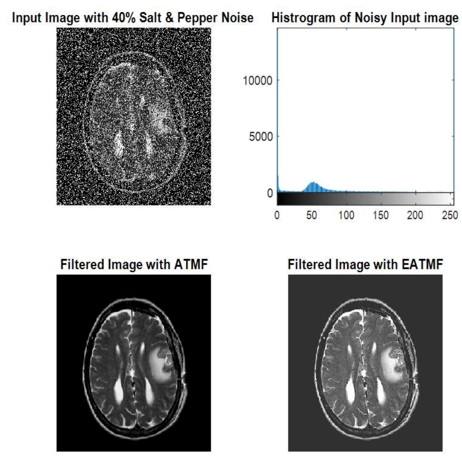

Figure 8: BRAINIX image with 40% Salt & Pepper Noise

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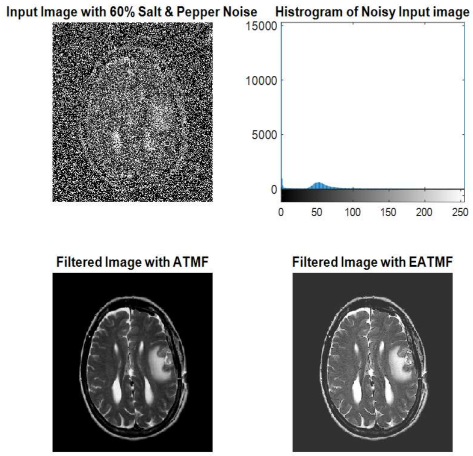

Figure 9: BRAINIX image with 60% Salt & Pepper Noise

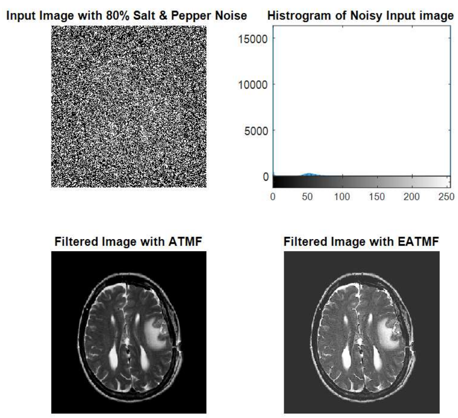

Figure 10: BRAINIX image with 80% Salt & Pepper Noise

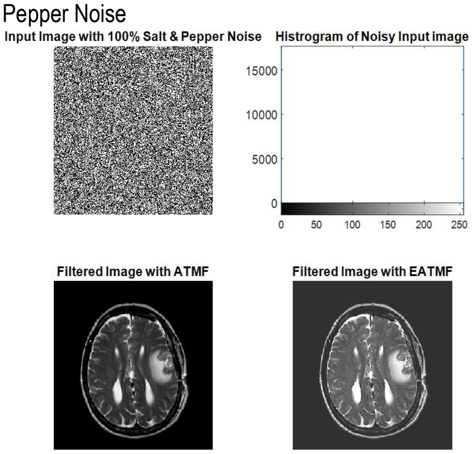

Figure 11: BRAINIX image with 100% Salt & Pepper Noise

CONCLUSION

This paper presented an EATMF algorithm aimed at effectively addressing the challenge of removing wide range of medical image noise. The EATMF algorithm, combines the ATMF with different thresholds and Laplacian filter was proposed. The EATMF algorithm can denoise medical images at different densities, while maintaining a balance between noise reduction and image quality. Experimental results demonstrate that the proposed method outperforms the ATMF approach in terms of achieving higher PSNR values. The algorithm exhibits consistent and reliable performance across different images corrupted by noise.

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