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IMAGE ENHANCEMENT AND DE-NOISING TECHNIQUES OF MAGNETIC RESONANCE IMAGES

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Graphical abstract

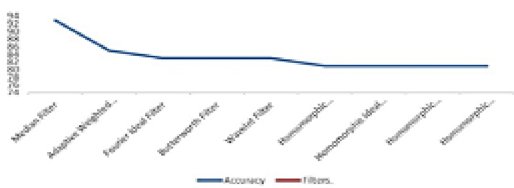

Image Enhancement by
Median Filtering shows high accuracy,
Morphological Operators
Histogram Equalization

Abstract

Medical images have noise, such as salt and pepper, speckle, and gaussian noise. So, getting the accuracy of magnetic resonance images is challenging always. The accuracy of brain images is essential for the clinical diagnosis process. The nonlinear method of median and morphological filters is used for enhancement, contrast adjustment, and histogram equalization for medical images and speech processing, to preserve them from noise and edge features. Because of its edge-preserving properties, this median spatial filter window is critically important and better for removing impulsive noise and speckle noise. Nine different shapes of windows and five different sizes of windows and five noise density injections are used for evaluating the performance of the median filter. The first person J.W.Tukey, did the smoothing process by median rank selection filter. The denoising using morphological process is also considered for analysis. These two nonlinear methods like median filtering and morphological methods are used for the restoration of noise from the original image. These two methods are applied in normal and seizure-affected images to calculate quality assessment metrics and also the performance evaluation metrics from magnetic resonance images. Any image needs to be denoised to get the accuracy, precision, and F-measure kind of common feature evaluation metrics. This paper evaluates two nonlinear filtering methods and their performance evaluated based on shapes and size of windows and for suppressing or de-noising to produce original noise-free images to assist clinically.

Keywords: Denoising, median filters, morphological, seizure, magnetic resonance images

1.0 INTRODUCTION

Medical images give exact visualization and reliable information for complaint opinion and treatment. To attain noise-free medical images, different methods are used. The standard enhancement methods are median filter, contrast adjustment of morphological enhancement, histogram equalization, contrast adjustment, alpha trimmed mean filter, recursive mean separated histogram equalization, sub-band wavelet filter, unsharp masking, and a combination of contrast adjustment. The denoising is to remove noise and preserve the edges. In linear methods, noise removal has the limitation of speed execution and edges of the images are not preserved efficiently. Hence, the blurred out happen in any edges, which are identified through the image discontinuity of pixels. So, the nonlinear methods are found to be more efficient to handle the image edges than the linear methods. The process of splitting those noises from the original signal without affecting its features is a herculean task. A median filter and morphological process should do the efficient way of smoothing spiky noise and preserving sharp edges, whereas linear filtering blurs such edges [1]. To improve the image quality, the kernel size of 3x3 filtering is used to produce the fragile nature of the images. The vascular density is carried through the generated binary images from image segmentation by grey level thresholding and then the two-dimensional images are smoothed with three, five, eight, and ten window sizes. The two hundred and fifty-five pixels was used to find the vessel area and the tissue area. The volume of the entire section is calculated by the ratio of entire section of the vessel and tissue area. The filters used in general are median filter, adaptive and weighted median filter, Fourier ideal filter, Butterworth filter, wavelet filter, and the different types of homomorphic filters. The signal features of the de-noising method are used to remove the unwanted noises. To remove noises, these filters are used in the first step of image enhancement. It is used to either detect edges or enhance an image. The image transformation is done to get a more accurate image by removing the unwanted noise [2]. To consider the neighboring pixels, the noisy image pixels can be filtered through the smoothing process. So far, there is no standard method used for the removal of noise from the original images. The different algorithms are used based on either the noise type or the noise distribution available in the images. So, the affected and unaffected images, are mostly used to remove noises and to calculate mean values which modifies the original image pixel value. The median filter and morphological filter are the best to calculate the de-noising power [3] and efficiency. But the disadvantage of the noisy pixels changed by median value without checking the edges of the real images [4]. So, the edges of the images are not regained to the original view sufficiently, when the noise level is increased. The morphological enhancement does the contrast stretching and unsharp mask with sub-band wavelet filters [5]. So, the median filter and morphological enhancement methods are examined in this paper for noise reduction of MRI images and to calculate an accurate image value.

Medical Image Noises

The difference between noise and sound depends upon the listener and their situation. The music is a pleasurable sound to one person and an annoying noise to another person. The image noise is caused by the variation of color and brightness in the images, and the electronic noise is caused by the movement of electronic components through random thermal motion, which reduces the reliability and quality of the images. It can be produced by the digital camera, sensor circuits, and image scanner. Image noise is originated in film grain as an unavoidable shot noise. If the image is captured in an undesirable way and at the wrong angle, the image will have hidden noise [6]. The main factors which influence the noise images are the camera, mobile phones, and visual media. The quantization and the discrete source of the transform method are also used to reduce the noise. Gaussian noise can be seen mainly in natural images. The MRI images have Rayleigh noise, Rician noise, and Gaussian noise [7]. The quality of an MRI image depends on the spatial resolution and contrast of an image and the artifacts of signal and contrast to noise ratio. The median filters are mainly used for the complex wavelet transform method for denoising purposes. The noise reduction and generation of edges are explained in the gradient method [8], which has been depicted in the Figure 1. The research studies show that the noise reduction in images is analyzed by the Principal Component Analysis method (PCA). The denoising methods can be classified with data redundancy and their sparseness properties. The first initiative method is the non-local means (NLM) filter method, which is used for noise reduction by exploiting the image pattern similarity index by an averaging method.

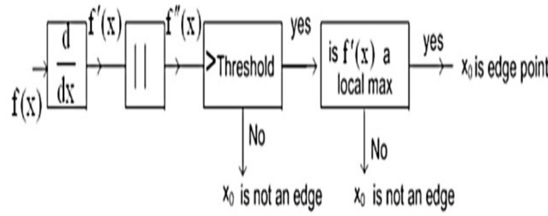

Figure 1 Noise reduction and generation of edge on Gradient Method [8]

The original signal is projected as an orthogonal space and variance, which is accumulated with noise, which is not sparse and spread uniformly throughout the components [9]. In medical image denoising, edge-preserving filters are also preferred because they will not degrade smoothing due to morphological edges [10]. The quality indices of edges are not compiled with the quality ratings or to the noise level. So, the low-rank filtering can be used to improve SNR effectively [11]. The edge blurriness of histograms is to calculate the final blur metric of an entire image through probability distribution [12]. Different kinds of filters are used to clean the real image from unfavorable noise [13]. The noise in magnitude images and the noise distribution in phase images need to be compared for better understanding. The salt and pepper noise has bright and dark pixels and also has dark and bright regions alternately. The corruption of large impulses is compared with the signal strength and impulse noises, and both are digitized to make an image [14]. In the object of the coherent image, the speckle noise and granular noise are the different types of noise [15], which create transmission errors and degrades the quality [16]. The adaptive filtering method is also used to increase the noise ratio of the signal and keep the important edge information of both the 2D and 3D medical images, which provide higher SNR and sharper edges of images [17]. The MRI image has corners and thin lines, which are either anatomical or metabolic structure information of the human body. These structure damages are more unacceptable than the noise. So, the filters are very essential to eliminate the noise and maintain the high-frequency signals of images [18]. De-noising has frequency, spatial, smoothing, sharpening and wavelet domains and filtering is employed for noise reduction, re-sampling, and interpolation. The different types of noise are removed efficiently by different filters [19]. The morphological method is used to shrink, remove or fill in boundary pixels of an image. Threshold with the histogram-based approach of MRI also gives a better understanding [20]. Image quality is improved by median filters, used for the sorting networks and histogram-based methods [21]. The transform domain used in feature extraction techniques for classifying the normal and abnormal seizure images using enhanced methods is discussed. In this method, the image features are extracted by the frequency domain method because the visual analysis of clinical system images should be processed in a multi-scale way [22, 23].

Table 1 shows the literature survey of the studies which is done on the previous studies

Table 1: Median filter limitation based on literature survey

Author	Methodology	Merits	Limitations
Petrou 2010 [31]	All pixels are replaced with a median of the window by a simple filter.	Impulsive and split noise removed	All pixels are the same and edges are not preserved.
Esakkirajan et al., 2011 [32]	The decision- based unsymmetric trimmed filters are mean and median.	All neighbor pixel is corrupted	Noise density is 80% and above, the images are improper.
Pavic and Novoselac 2015 [33]	The corruption ratio is the low noise-contaminated images by adaptive centered weighted image.	The impulsive noisy areas are considered with noise density area	The corruption ratio does not suit all pixels.
Das et al., 2016 [34]	Adaptive window (maximum > median > minimum) by selective adaptive method	Selective filtering	Highly dense areas are required.
Ha et al., 2016 [35]	Adaptive window of conditions-I and II method	Selective filtering	High noise density and blur image.
Sathua et al., 2017 [36]	To replace the pixel with mean by adaptive approach.	The different noise regions are considered	The salt and pepper noise are uniform
Sukumar and Selvi, 2018 [37]	Mean, Median and Fuzzy Noise Detector are used	The fuzzy approach selects the noisy pixels	Image blur in images
Kishorebabu and Ramachandran, 2019 [38]	Unsymmetrical trimmed median, and modified mean and global mean of different morphological filters	Multifaceted nature	High noise density and image blur
Sriparna Banerjee and Sirrundhati Misra 2020 [39]	Image Enhancement and morphological process	Applied in synthetic aperture radar images	To avoid speckle noise, wavelet domain methods are used
Ashpreet and Mantosh Biswas 2021 [40]	Denoising method and enhancement are experimented by different filters	Applied for color images	Blurring methods are used
Chen et al 2006 [41]	PUF (Progressive Umbra filling) procedure of a morphological process	Gray color images are used	Adaptive signal smoothing methods A noise-free pixel counter (NPC) method is used.
Lin, Shih-Chia Po-Hsiung, [42]	Morphological pixel dilation method	Candy images	

The original image gives the degrading factors like blurring and noise that are eliminated by restoration. The mid-max detector-based filters are used for restoration purposes [24]. The input image is split into two parts by histogram and its mean before equalizing, so the image brightness is preserved [25]. The nonlinear filter technique is used for the color and texture segmentation method. The CNN-based denoising methods are used for mapping by optimizing function loss on a training set that has degraded a clean image. The feed-forward trainable diffusion model also produces a better denoising effect. The CNN gives the knowledge of high-level features by using the hierarchical network [26]. The morphology process is used for Euclidean space correction of gray images [27] and for filtering thin nets in the gray ton images [28]. The global filtering approach is used in the morphological process for restoring the old film archives [29]. The foreground and background segmentation methods are also used for the morphological reconstruction of the images [30]. The above Table 1 presents the literature survey for further studies [31-42].

2.0 METHODOLOGY

The morphological process restores image from noise, shape, and size. This is done by alternative sequential filters, smoothing, and sequential filters, which are mainly used to preserve the crucial input image structures [43]. The image enhancement method is used to do de-noising, filtering, histogram equalization, interpolation, re-sampling, and noise reduction [44]. The spatial domain and statistics filters are nonlinear median filters. They remove noise by smoothing and decreasing the intensity of the pixels. The median filter is used to replace the pixel value within the image [45]. Noise suppression is done by median filtering by the input image pixel, which has the kernel frame and at the coordinates of the kernel center in which the output pixel is located [46]. The original image has (m,n) kernel frame based on the median value of pixels. The output is set to this median value with the coordinates of pixel (m,n) and without the smoothing characteristics. The edges and image intensity are not affected in the magnetic resonance images with respect to their gray level intensity [47]. This nonlinear filtering method is used to remove the shot noise from the image without attenuation and median window slides pixels are processed without intensity [48]. The pixel values in the windows are 3, 5, 6, 55, 10, and 15. The output of the given pixel location is 10 processed from the pixel value of 55, with the median window value being 5. The filters used has two impulsive values with noise, the output is without noise and signals distortion. It is used to do edge detection and analysis. The results are found based on the gradient method.

Median Filter method

The median filter algorithm detects the noisy images in searching regions of window size 3x3, 5x5, 8x8, and 10x10, the fitness value of optimization is adjusted based on the peak ratio of signal and noise. The values are compared with the bilateral filter parameters of both clinical and simulated MRI images. The median filter with different window size gives low and high noise density values of MSE from RGB grey image and the image affected salt and pepper noise. The median performance is increased due to the increase in window size and then image gets blurring effect; it is decreased due to the increase of noise density [49]. Original MRI images are converted to gray scale filtered double class image, using median filter window sizes of 3, 5, 8, 10. This paper presents two methods of image enhancement. In the first method based on the median filtering. The Figure 2 to Figure 6 analyses the MRI of brain, healthy control of adult and child T2 weighted images, refractory focal on set epilepsy image and the refractory focal seizure images for processing and results are captured below.

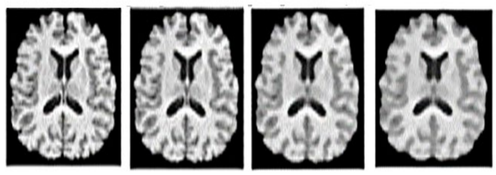

Figure 2 Original RGB image of MRI Head, Gray scale filtered double class image of median window size of 3, 5, 8, 10

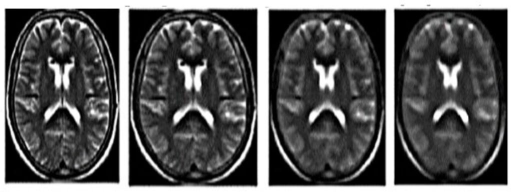

Figure 3 Original RGB image of Normal Adult T2 image, gray scale double class image of median window size of 3, 5, 8,10

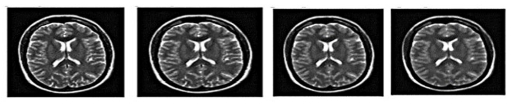

Figure 4 Original RGB image of Normal child T2 image of median window size of 3, 5, 8, 10

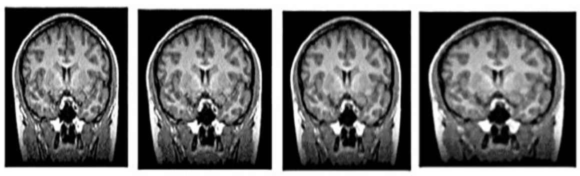

Figure 5 Original RGB image of refractory Focal Onset Epilepsy, gray scale filtered double class image of median window size of 3, 5, 8, 10

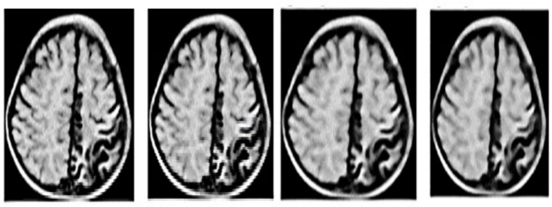

Figure 6 Original RGB image of refractory Focal Seizure, gray scale filtered double class image, of median window size of 3, 5, 8, 10.

3.0 MORPHOLOGICAL PROCESS METHOD

The morphological process is mainly used to maintain the output images with intensity modification and same as input image with morphological correction.

Figure 7 Original MRI Head image, Eroded image, Mid stretched image, Median filtering image, Gray-dilated 1,2 and 3

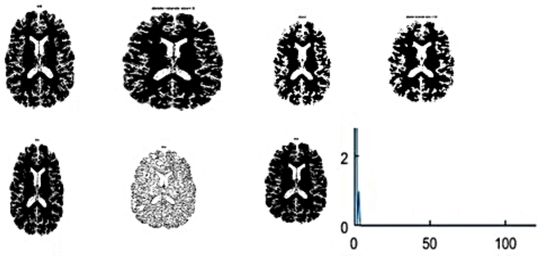

Figure 8 Bandwidth image, delete islands<5, Dilated image, Delete islands<30, Band width Variation 1,2 and 3 Histogram variation intensity value on x axis and frequency value on the y axis.

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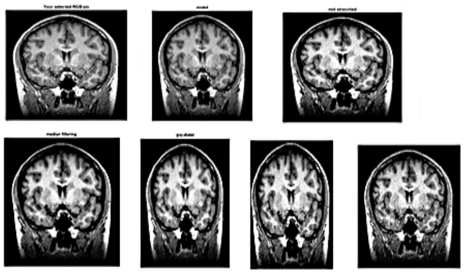


Figure 9 Original Onset focal Epilepsy, Eroded image, Mid stretched image, Median filtering image, Gray-dilated 1, 2 and 3.

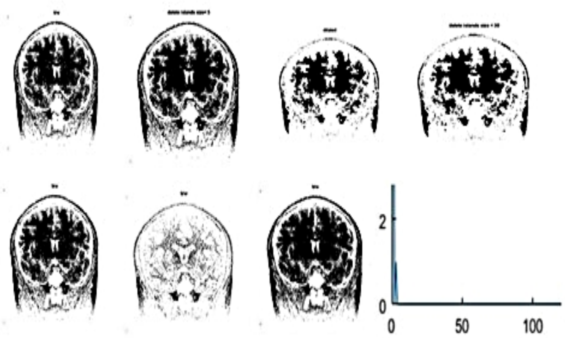


Figure 10 Bandwidth image, delete islands<5, Dilated image, Delete islands<30, Band width Variation 1,2 and 3 Histogram variation intensity value on x axis and frequency value on the y axis.

Table 2 Mean and Threshold values of the Normal and Epilepsy affected images of the Morphological process

Refractory Onset Focal Epilepsy image values		MRI Head Image values	
Image(real)	250	Image(real)	413
Image(compressed)	200	Image(compressed)	317
Mean	**Threshold**	**Mean**	**Threshold**
0	0.4588	0	0.3804
-0.5	0.9588	-0.5	0.8804
-0.1	0.3588	-0.1	0.2804

Table 2 depicts the mean and threshold values of the normal and Epilepsy affected images through the morphological process. Histogram Enhancement also used for the contrast stretches like adjusting intensity and contrast of the images are shown from Figure 11 to Figure 15.

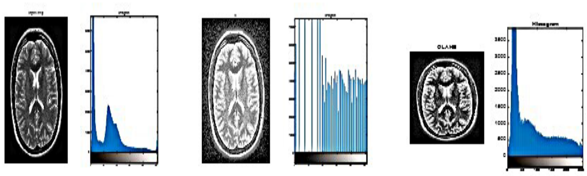
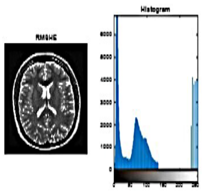


Figure 11 Original image HE **Figure 12** PSNR_ HE **Figure 13** PSNR_CLAHE



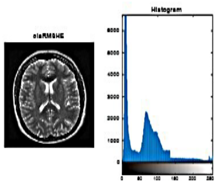


Figure14 PSNR_RMSHE **Figure 15** PSNR_CLARMSHE

Table 3 Histogram Enhancement values of the Normal child T2 images

PSNR_HE	PSNR_CLAHE	PSNR_RMSHE	PSNR_CLARMSHE
10.1067	17.186	22.3495	40.7803

Table 3 depicts the values of PSNR-Peak signal to noise ratio, HE-Histogram Enhancement, CLA-Contrast limiting adaptive and RMS-Root mean square

To sharpen the images [50], the morphological filters are used and their basic operators are erosion and dilation. The neighborhood brightest value is selected by dilation and neighborhood darkest value is selected by erosion. The opening and closing operation done by these morphological operators. The opening and closing of images are followed by erosion and dilation, whereas dilation followed by erosion [51-52]. The morphological process used to establish the relation of basic morphological operators through restoration. The denoising using morphological process of the non-linear method is explained in the Figure 7 and Figure 8 for normal MRI head image and Figure 9 and Figure 10 for Epilepsy affected image, both are analyzed through the process of eroded, stretched, dilated and band width variation methods. Mean value is calculated by sum of pixel values divided by the total number of pixel values. Pixels above the threshold value are converted to white (one bit) The non-Linear operations based on the morphology of features and shape of the images.

4.0 RESULTS AND DISCUSSION

The Results are clearly discussed in the below sections.

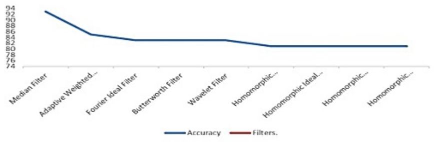


Figure 16 Accuracy of Median filters compared with the existing filter

Table 4. Quality Metrics of MRI images

IMAGES	SSIM	MSE	PEAK SNR	SNR
Normal Adult T2 image	0.6475	227.7403	40.5092	30.7263
Normal child T2 image	0.8288	260.7664	41.9502	31.6567
MRI Head	0.7915	183.7424	42.7584	37.9461
Refractory focal onset Epilepsy	0.7835	243.5358	41.6869	33.8133
Refractory focal seizure image	0.8261	263.5408	43.8407	37.4279
Temporal lobe epilepsy	0.9127	252.4143	42.3356	34.5206

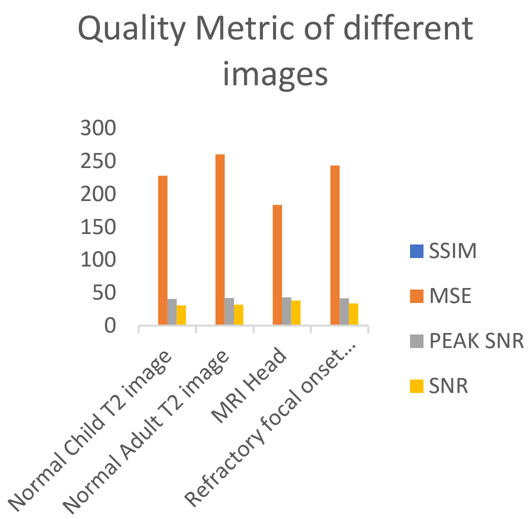


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Figure 17 Quality Metrics of different images (x axis shows the types of seizure and healthy control and y axis shows on various quality metric values)

Table 5. Feature Extraction metrics of MRI images

IMAGES	Accuracy	Sensitivity	Specificity	F-Measure
Normal child T2 image	0.8315	0.1775	0.9001	0.1666
MRI Head	0.3914	0.0770.	0.8487	0.1304
Refractory focal onset Epilepsy	0.7042	0.1262	0.8991	0.1770.
Refractory focal seizure image	0.5792	0.1439	0.9215	0.2313
Temporal lobe epilepsy	0.7115	0.1088	0.8932	0.1488

Table 4 depicts, structure similarity index (SSIM), Mean squared error (MSE) for image quality estimator and Peak signal to noise ratio (PSNR) for reconstructing the image structure through quantification methods. Signal to noise ratio (SNR) is used to characterize the quality of images. The results of classification and feature extraction metrics of images are presented in Table 5. Accuracy is the percentage classification of the image. Sensitivity was calculated from the thermal noise image Specificity is the predictable image value. F-measure is used to combine the precision and recall in a single measure.

The image enhancement methods of denoising and morphological process are used and the results are discussed in this paper. The median filter accuracy is more compared with other filters and it is best for the noise suppression of brain MRI, Healthy control of adult and child image and focal onset Epilepsy and refractory Seizure affected images are used and the results are analyzed by using MATLAB R2021a. The results of quality metrics are measured and compared with the healthy controls. The accuracy of the median filter is shown in the Figure 16. The Quality metrics of the images are shown in Figure 17. The Quality metrics and Feature extraction metrics of the Normal and Epilepsy Seizure affected images are listed in Table 4 and Table 5. The future work may be focused by testing with high pass filters and various image enhancement methods and the results obtained will be helpful to detect the abnormality of the brain.

5.0 CONCLUSION

This work shows the two methods of non-linear filtering algorithms used to restore the noise from medical images. These methods have been compared with qualitative parameters of MSE, PSNR and SNR and the results have been compared with the standard pattern of noises and performance of images, which was calculated through common classification model evaluation metrics. This method will improve the MRI image quality for easy diagnosis. In this process the image creates a new non zero value pixels of images. The study shows that the high-quality image reconstructed by the median filters and morphological process. The other filters like Gaussian, Salt and pepper denoising methods are used to do the noise variance. The average filters are also performed better for speckle noise removal. To compare with other existing methods, this study proves that the median and morphological filters also will produce the better denoising through preserving the structures and intensity threshold values.

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