Noise Removal from Medical Images Using Hybrid Filters of Technique

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Abstract. In this paper noise removal from the medical images using the hybrid filter of technique is presented. From the last couple of decades, medical image processing and analysis techniques based on computing algorithms acquired prominence as an alternate skillset for medical experts in disease diagnosis and prevention. As the number of patients are increasing yearly, doctors don’t have enough time to calculate the actual information from the medical images, as most of the medical images are affected by the noise. Medical images contain a different kind of noises because several machines are operating for data acquisition and transmission, so in order to reduce the complexity from the radiologist point of view we were very much interested in the design of an algorithm which can be beneficial and useful at the convenient level. Image Processing has become a very prominent technique in medical image analysis and medical image processing. The proposed architecture is the amalgamation of morphological operations, A modified form of Median Filters and Wiener Filters. The boundary and the shape of the image is extracted through Morphological operation. For noise removal and enhancement purpose modified median filter and wiener filters were used. The parameters like Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Root Mean Square Error (RMSE) are determined through proposed algorithm. Overall results indicate that the enhancement quality is performing well in proposed technique.

1. Introduction
Since the last two decades, inventions in electronics have specially made easier for the detection of harmful diseases. Digital image processing is playing a very useful role in our daily life applications and also in industrial applications. In our everyday life, we use many digital image applications such as ultrasound, x-rays, dermoscopy images (DI), magnetic resonance imaging, computed tomography and ultrasound (US) [1]. These images contained useful information on the sections of the human body [2]. Unfortunately, there are several types of noises, that degrade the medical images. These noises include salt and pepper noise, Gaussian, Impulse and Poisson noise [3]. This noise consists of two constant values which are distributed randomly throughout the image [4]. The noise needs to be removed from the images. Noise is the unwanted disturbance produced in the image. Noise may produce due to several reasons. Noise can be induced inside the image due to the architecture of the machine itself, which is used for taking the image. The noise removal process is a very important part because if there is a noise
In the image we cannot get the proper information as noise obscures the information content. Without getting the proper information it is very difficult for the doctors to diagnose the disease properly. While we are transmitting and receiving the image noises add to the image which may hide the actual information.

In literature, there are several filtering methods have been proposed for noise removal, generalized trimmed mean filter [5], mean and median filter [6], generalized morphological filter [7], adaptive median filter [8], wavelet filters [9-10], homomorphic and adaptive order statistics [11], curvelet filters [12] and fuzzy algorithms [13-14]. The noise in medical images is a crucial issue. The loss in image may lead to severe results for the patients, and may prove fatal to the life a person. We wanted to develop a method that can assist pathologists for examining the disease by using CAD system. A simple noise reduction technique conserves the information of the image and removes the noise at the same time. To avoid the damage of uncorrupted pixels, two-step filtering methods [15-16]. The idea in this study is to demonstrate a method that can detect and remove the salt and pepper noise. The physician cannot analyze the image with precision and accuracy if the image contains any noise. Therefore, it is essential to eliminate the noise from the medical image. The medical image may encompass diminutive information about heart, lungs, stomach, brain, nerves, or more.

X-ray and CT are very powerful methods. They are used to get the information about the internal structure of the object. They operated for non-destructive testing of the materials. The CT image is derived from a massive number of systematic observations of various viewing angles, and with the support of a computer (Radom transform); the final CT image is then reconstructed. It is very difficult to save the life of a human being who is suffering from harmful disease and whose medical image is corrupted by noise. De-noising of MRI scanned image is a major research area for both image processing and biomedical engineering. In general, medical images are affected by the noise. The distortion is added in the medical images due to this noise, as noise contained irrelevant and unnecessary information. This information tends to mislead the actual information and hide the quality, authenticity of the image. Among the reasons of image quality degradation may be the poor illumination, contrast, or finite sensitivity of the imaging device. Images may be corrupted due to the electronic sensor noise or environmental instabilities leading to broadband noise. Aliasing is another factor which may cause the image quality to a low standard. Finite aperture effects or motion also leads to spatial disturbances.

For a correct diagnosis, the medical experts need certain features that are clearly visible. Different imaging factors may be used to minimize the noise level in the medical images. In an X-Ray imaging, the fundamental factor is that for how much time the patient is exposed to the ray and how much doses of X-Ray is applied to the patient. In MRI imaging the fundamental factor is only time which is used for capturing the image. It is clear that if the dose of an X-Ray is high than the noise level of the image will be very low, but in the meantime, it is hazardous for the patient. Similarly, if the imaging time is high, the noise level in the MRI image will be very low, but again, it is dangerous for the patient. Keeping the point of the health of the patient in view, neither we will provide him a high dose during X-Ray nor we will ask him to stay for a longer period of time during MRI Imaging. De-noising from the medical images is required for further analysis of the disease and for the data acquisition.

2. Proposed Algorithm

In this work, we have proposed a new technique for the removal of noise from the medical images which are captured by using different machines and then transmitting from one place to the other place. This paper also shows how we can enhance the image, so that we can get a better view of the image after the noise removal which is very essential for the correct diagnosis of the diseases. The steps of the proposed algorithm are described below.

Steps:
1. Given MRI image as the input
2. Convert the image into Gray Scale Image
3. Apply morphological operations
4. Calculate the threshold value
5. Obtain the histogram equalizer
6. Apply the Modified form of the Median Filter for preserving the edges of the image.
7. Apply the Wiener Filter to achieve the noiseless image.

3. Methodology

In this section, we will explain the complete method for our proposed algorithm. The complete working of the algorithm is described in Figure 1.

**Input Image:** MR image is taken as the input of the system. We calculate the size of the image. Retrieve the size of the image in a specified file.

**Gray Scaled Image:** The input image is then converted to the gray scaled image. The gray scaled image is necessary for further processing. The fundamental reason of doing so, we have ranges, now from 0 to 255 and every value between these two values will indicate the different point of the image. Noise randomly adds in every image. We are assuming that the input image has some sort of noise.

**Thresholding:** Thresholding is applied on the noisy images to remove the noise. There are two types of thresholding techniques.

(i) **Soft Thresholding:** Soft thresholding works on the principle of shrink or kill.
(ii) **Hard Thresholding:** Hard Thresholding works on the principle of the keep or kill.

Different methods can be used for the calculation of the threshold value. We calculated the threshold value by using the ‘Sobel’ operator. The operator was used for the edge detection. After calculating the threshold values, we applied the “fspecial” command which creates the two dimensional filter.

**Modified Median Filter:** Median filter belongs to the class of non-linear filters. It is very powerful non-linear filter. It reduces the variation present between the adjacent pixels. The fundamental principle of this is to replace the pixel value to the median value. The median value is calculated by arranging the pixel values in ascending order and then calculating the middle value. The median filter is used for salt and pepper noise. Table 1 is describing the working of the median filter.

![Flow Chart of the Proposed Algorithm](image)

**Table 1. Explanation of working of Median Filter**

|   |   |   |
|---|---|---|
| 10 | 11 | 13 |
| 20 | 21 | 19 |
| 39 | 23 | 31 |

First of all we need to re write the pixel values in ascending order.
Here the median value is 20, so we need to replace the highlighted value to the median value. We applied modified median filter with different window size and then calculate the median. The working of the modified median filter is shown in the figure 2. We applied the modified median filter with cross mask and we obtained the median value. Again, we applied median filter with x-mask and we have another median value. For modified form of median filter, we then take the median of the first two median values with the actual value itself. The following figure shows the modified form of median filter. It also explains how we are calculating the median value. Instead of taking one median value, here we are taking the median value and calculating the median value. By doing so the results of preserving the edges are more stable.

![Figure 2. Modified form of Median Filter](image)

After calculating the median of the image we connected the output of the modified median filter into the wiener filter. The steps of the algorithm for the modified form of median filter are given below.

1. Select the filter size and window on the element
2. Select the elements according to the filter size
3. Re-arrange the selected elements
4. Select the middle value (as like ordinary median filter works)
5. Select the diagonal values over the selected element
6. Select the elements according to the filter size
7. Re-arrange the elements
8. Pick the middle value
9. Pick up the results from point 4, 8 and the element itself
10. Re-arrange these three elements
11. Pick the middle value as the modified median value

Figure 3 shows the working of the complete architecture of the proposed methodology.

![Figure 3. Proposed combination of filters](image)

There are numerous filters available, which can eliminate the noise from the medical images. However, in this study, we preferred wiener filter due to its’ advantages and robustness over other non-linear filters. The wiener filter is used for the reduction of the noise from the images. It works on the principle of optimal way. It calculates the mean square error. Noise reduction is done by the comparison of the received signal to the desired noiseless signal. The input of the wiener filter is stationary. It uses
the statistical approach for the achievement of the goal. Signal and noise both assumed as linear stochastic processes. The equation of the wiener filter is given below.

\[ X_n(u,v) = W(u,v) \cdot Y(u,v) \]  

Here \( Y(u,v) \) is the received signal and \( X_n(u,v) \) is the restored image. It uses for linearization of the blurring effect of the image. It helps in controlling the Signal to Noise ratio (SNR).

4. Experimental Results

In this section we have provided the experimental results. Experimental results are based on the images taken after every step. The following figure 4(a) shows the original image. After obtaining the image we convert it into gray image. The result of the gray image is shown in figure 4(b). Figure 4(c) displays the result of noise added to the medical image. Salt and pepper noise inherently exists and degrades the quality of the medical images such as ultrasound and optical CT images. In order to attain better results, we converted the noisy image into gray scaled image. The output of the gray scaled image is shown in the following figure. After converting the noisy image into the gray scaled image, we use the edge detection method. This method was used to detect the edges of the input image. The following figure 4(d) shows the result of the Gaussian low pass filter. Since our aim was to develop an algorithm which can reduce the noise level and to enhance the visibility of the original image. For that particular purpose we have designed a hybrid filter. This hybrid filter is the combination of the Modified form of Median Filter and Weiner Filter. The median filter is used to remove the noise. It acts similar to the mean filter but preserve the edge information of the images. It also preserves the detail information of the image which is necessary for further steps. The result of the modified form of median filter is shown in the figure 4(e).

In the last step, we applied wiener filter to remove the noise from the image so we can get the noiseless image and the edges of the image are conserved due to the usage of the Gaussian low pass filter. The wiener filter is used to reduce the noise completely from the medical image. That image has affected due to the unwanted signals. Most filters operate on the principal of frequency response, however, wiener filter implies different approach and has a different view of angle since it uses the statistical approach. The result obtained from the wiener filter is shown in the figure 4(f).
Figure 4. Results of the proposed algorithm for the noise removal from the medical image. Original Colour Image (b) Gray Image (c) Image with noise (d) Result of Gaussian Low Pass Filter (e) Result of the modified median filter (f) Result of the wiener filter

5. Objective Measures

The most frequently used method for the objective measures are Root Mean Square Error [RMSE], Maximum Absolute Error [MAE], Signal to Noise Ratio [SNR], Peak Signal to Noise Ratio [PSNR] and Mean Square Error [MSE]. We calculated all the above stated quantities. The results of the above mentioned quantities are calculated by the following formulae.

\[ MSE = \frac{1}{NM} \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \left[ f(i,j) - f'(i,j) \right]^2 \]  

\[ \sqrt{MSE} = RMSE \]  

\[ MAE = \max |f(i,j) - f'(i,j)| \]  

\[ SNR = 10 \log \left( \frac{\sum_{i=0}^{N-1} \sum_{j=0}^{M-1} f(i,j)^2}{\sum_{i=0}^{N-1} \sum_{j=0}^{M-1} [f(i,j) - f'(i,j)]^2} \right) \]  

\[ PSNR = 20 \log \left( \frac{(255)^2}{MSE} \right) \]  

The result of SNR and PSNR is calculated in decibels (dBs). From the above equation \( f(i,j) \) represents the original image and \( f'(i,j) \) represents the final image obtained after the Wiener Filter process. The following table 2 shows the result of the RMSE, MSE, SNR and PSNR. Here we are using salt and pepper noise. We are changing the image size and the noise intensity level at the same time.

Table 2. Performance Evaluation of the proposed Algorithm in terms of RMSE, MSE, SNR, PSNR (Fixed Noise Level)

| Noise Level | Image Size | RMSE  | MSE   | SNR dB | PSNR dB |
|-------------|------------|-------|-------|--------|---------|
| 0.07        | 492 * 474  | 5.78  | 33.47 | 11.23  | 32.91   |
| 0.07        | 486 * 468  | 5.97  | 35.66 | 11.38  | 32.64   |
| 0.07        | 432 * 416  | 6.08  | 37.06 | 11.41  | 32.47   |
| 0.07        | 378 * 364  | 6.17  | 38.19 | 11.44  | 32.34   |
| 0.07        | 297 * 286  | 6.20  | 38.47 | 11.64  | 32.31   |
The following table 3 shows the results of the MSE, RMSE, SNR and PSNR of a single image. We consider image of size 297 * 286. We changed the noise density level and then calculated the above stated values.

Table 3. Performance Evaluation of the proposed Algorithm in terms of RMSE, MSE, SNR, PSNR (Fixed Image size)

| Noise Level | Image Size | RMSE | MSE  | SNR dB | PSNR dB |
|-------------|------------|------|------|--------|---------|
| 0.02        | 297 * 286  | 6.12 | 37.46| 11.72  | 32.42   |
| 0.06        | 297 * 286  | 6.16 | 37.97| 11.62  | 32.37   |
| 0.11        | 297 * 286  | 6.17 | 38.04| 11.59  | 32.36   |
| 0.15        | 297 * 286  | 6.17 | 38.09| 11.52  | 32.35   |
| 0.18        | 297 * 286  | 6.21 | 38.61| 11.44  | 32.29   |

Noise has a Gaussian distribution, that depends upon the mean and standard variation. The mid value of the graph is calculated by mean, whereas, standard deviation describes the height and width of the graph.

6. Conclusions
We have taken the MRI image and added some Gaussian noise with mean and variance. After adding the noise, we implemented our proposed algorithm. From the figures we conclude that the proposed algorithm is sufficient enough to reduce the noise from the image. On the other hand, due to the presence of the hybrid image the quality of the image is also not decreased. Therefore, we believe that by using this modified technology for the medical imaging we can really reduce the time for the pre diagnosis of the disease. Whereas the modified form of median filter is providing better result by keeping the edges preserve as compare to the any other form of the filter. From the output images we can clearly visualize that wiener filter is providing the desired results for the image.

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References
[1] Chanu, P.R. & Singh, K.M. J Med Syst (2018) 42: 197. https://doi.org/10.1007/s10916-018-1057-8
[2] Muhammad Aqeel Aslam, Daxiang Cui, Brain Tumor Detection from Medical Images: A Survey. Nano Biomed. Eng., 2017, 9(1): 72-81. DOI: 10.5101/nbe.v9i1.p72-81.
[3] P. Gravel, G. Beaudoin and J. A. De Guise, "A method for modeling noise in medical images," in IEEE Transactions on Medical Imaging, vol. 23, no. 10, pp. 1221-1232, Oct. 2004. doi: 10.1109/TMI.2004.832656
[4] Hossein Khani, Z., Hajabdollahi, M., Karimi, N. et al. J Med Syst (2018) 42: 216. https://doi.org/10.1007/s10916-018-1074-7
[5] Abreu E, Lightstone M, Mitra SK, Arakawa K. A New efficient approach for the removal of impulse noise from highly corrupted images. IEEE Trans Image Process. 1996;5:1012–25.
[6] Rytsar YB, Ivasenko IB. Application of (alpha, beta)-trimmed mean filtering for removal of additive noise from images. SPIE Proceeding. Optoelectronic and Hybrid Optical/Digital Systems for Image Processing. 1997:45–52.

[7] Sawant A, Zeman H, Muratone D, Samant S, DiBianca F. Adaptive median filter algorithm to remove impulse noise in x-ray and CT images and speckle in ultrasound images. SPIE Proceeding Medical Imaging. 1999:1263–74.

[8] Chunhui Z, Qingbin X, Wei N. Study on the noise attenuation characteristics of generalized morphological filters. SPIE Proceeding Medical Imaging. 1998:236–9.

[9] Runtao D, Venetsanopoulos A. Generalized homomorphic and adaptive order statistic filters for the removal of impulsive and signal dependent noise. IEEE Trans Circuits Syst. 2003;34:948–55.

[10] Karthikeyan K, Chandrasekar C. Speckle Noise Reduction of Medical Ultrasound Images using Bayesshrink Wavelet Threshold. Int J Comput Appl. 2011;22:8–14.

[11] Wang L, Lu J, Li Y, Yahagi T, Okamoto T. Noise reduction using wavelet with application to medical X-ray image. International Conference on Industrial Technology. 2005;20:33–8.

[12] Cheng Y, Li Y, Xue D. Image Denoising Method Based on Curvelet Cycle Spinning. International Conference on Wireless Communications, Networking and Mobile Computing. 2008;13:1–3.

[13] Russo F, Ramponi F. A Fuzzy filter for images corrupted by impulse noise. IEEE Trans Image Process. 2000;3:168–70.

[14] Anisha K, Wilsey M. Impulse noise removal from medical images using fuzzy genetic algorithm. Int J Multimed Appl. 2011;3:93–106.

[15] Liang SF, Lu SM, Chang JY, Lin CT. A Novel two-stage impulse noise removal technique based on neural networks and fuzzy decision. IEEE Trans Fuzzy Syst. 2008;16:863–73

[16] Hore JE, Qiu B, Wu HR. Improved color image vector filtering using fuzzy noise detection. Opt Eng. 2003;42:1656-64.