# Comparative Image Quality Analysis of Spatial Filters for Pre-processing of CT Abdominal Images

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## Abstract

**Aim:** To determine the efficient noise reduction filter for abdominal CT images.

**Background:** Image enrichment is the first and foremost step that has to be done in all image processing applications. It is used to enhance the quality of digital images. Digital images are liable to addition of noise from various sources such as error in instrument calibration, excess staining of images, etc., Image de-noising is an enhancement technique used to remove / reduce noise present in an image. Reducing the noise of images and preserving its edges are always critical and challenging in image processing.

**Materials and Method:** In this paper, four different spatial filters namely Mean, Median, Gaussian and Wiener were used on 100 CT abdominal images and their performances were compared against the following four parameters: Peak signal to noise ratio (PSNR), Mean Square Error (MSE), Normalised correlation coefficient (NCC) and Normalised Absolute Error (NAE) to determine the best denoising filter for the abdominal CT images.

**Result:** Based on the experimental parameters, the median filter had the maximum efficiency in managing salt and pepper noise than the other three filters. Both Median and Wiener filters showed efficiency in removing the Gaussian noise. Whereas, the Wiener filter demonstrated higher efficiency in reducing both Poisson and Speckle noise.

**Conclusion:** Based on the results of this study, we can conclude that the median filter can be used to reduce Salt and Pepper noises. Median and Wiener filters are significantly better for Gaussian Noise and the Wiener filter can be used to reduce both Poisson & Speckle noise in abdominal CT images.

## Keywords

Novel Image Quality Analysis, Noise Reduction, Median Filter, Gaussian Filter, Wiener Filter, CT Abdominal Images.

## Introduction

Medical images obtained from Magnetic Resonance Imaging (MRI), Ultrasound, Computed Tomography (CT) etc play a vital role in diagnosing certain medical conditions and are also used for therapeutic conditions. Generally, during the image acquisition or transmission, a distortion can be caused, which leads to pixel misrepresentation of images (Gonzalez 2009). The changes in the image pixels are referred to as noise. Noise can impair the quality of the image and thus image pre-processing is required to overcome these distortions. So, de-noising with edge preservation of CT images is the preliminary step in pre-processing. For various noises such as Salt & Pepper, Gaussian, Speckle, and Poisson noises, filters such as Mean, Median, Gaussian, Poisson, Wiener can be used in pre-processing to denoise the image. Each image is processed using all these filters and the performance of the filters are compared for the following parameters: PSNR, MSE, NCC and NAE.

There are various filters to reduce the noise in the images. The usage of appropriate filters should be in such a way that noise should be removed while preserving its edges. (Gonzalez 2009; Kumar and Nachamai 2017) proposes that the response of the median filter is better for the salt & pepper noise and Poisson noise but the disadvantage is that it also removes the fine details of the image. Whereas for the Gaussian and Speckle noise, the Wiener filter performs better based on the evaluation of size, histogram and clarity scale of the images. (Gravel, Beaudoin, and De Guise 2004) concludes that Gaussian noise is the standard form of noise found in CT images. (Satapathy et al. 2017) proposes that for salt & pepper noise, the performance of adaptive median filter was better and for Gaussian noise, Gabor filter works well when frequency is equal to 0.02, else Gaussian filter is better. But in maximum cases Gaussian filters are better.

Few existing research articles have compared the Mean, Median, Gaussian, Poisson and wiener filters for CT images on PSNR, MSE, NCC and NAE parameters. Hence, this study was conducted on 100 CT abdominal images to analyse and determine which filter has the maximum efficiency.

## Materials and Methods

The Study setting of the proposed study has been done in our university. Four noise reduction filter groups were identified and applied for this experiment.

A total of 100 abdominal CT images were acquired from Saveetha Medical College and Hospital. Adequate measures including removal of name tags and image metadata were taken to maintain patient confidentiality. The G-power was calculated as 0.8 for the given samples. The sample size was computed as 7784 for each group. All the CT images were preprocessed individually using all four filters in MATLAB. Images were analysed for Salt & Pepper, Gaussian, Speckle, Poisson noises and their corresponding outputs were recorded under the following parameters.

1. MSE: Mean Square Error
2. PSNR: Peak signal to noise ratio
3. NCC: Normalised correlation coefficient
4. NAE: Normalised Absolute Error

### Noise Models

Noise in an image is the disturbance caused by any external factors while transmitting them electronically, or due to sensor malfunction (like heat, size etc). There are various types of noise found in the images (Gonzalez 2009). This paper considered the following noises for this study:

### A. Salt & Pepper Noise

Salt & pepper noise, also known as impulse noise occurs commonly during the data acquisition (Esakkirajan et al. 2011) (Chen, Hung, and Zou 2017) (Agrawal and Doermann 2009). The characteristics of this noise are that noisy pixels take either salt value (the white pixel in the dark regions) or pepper value (the dark pixel for white regions) (Gonzalez 2009) (Esakkirajan et al. 2011). So, randomly scattered black and white pixels appear throughout the image. Salt & pepper noise has only two gray values, 0 or 255 (Laskar et al. 2009). For salt noise, the gray level intensity is closer to 255 and for pepper it is closer to 0

(Chen, Hung, and Zou 2017). Salt and Pepper noise in digital transmission and storage is represented by equation (1).

$$I(t) = (1-e)S(t) + e\,N(t) \tag{1}$$

Where, I(t) represents the noisy image, S(t), and N(t) represents the number of dark pixels in the white portion and the white pixels in the dark region respectively, e{0,1} with probability p.

The probability density function is represented in equation (2) as:

$$y_{ij} = \begin{cases} \text{Zero or } 255 \text{ with probability } p \\ x_{ij} \text{ with probabilty } 1-p \end{cases} \tag{2}$$

$Y_{ij}$ is the image with noisy pixels, $X_{ij}$ is the uninterrupted image pixel, p is the total density of a noisy image.

## B. Gaussian Noise

Gaussian noise is a statistical noise which occurs during image acquisition ie., sensors, or can occur due to environmental factors, or even during image transmission (Boyat and Joshi 2015). It is also known as the Random variable impulse noise (RVIN). It has the probability density function (PDF) similar to that of the normal distribution and is represented in equation (3) as:

$$p(x) = \frac{1}{\left(\sigma\sqrt{2\pi}\right)} * \frac{e}{2\sigma^2} \tag{3}$$

where ‘x’ represents the intensity, the average of x is represented by ‘μ’ and ‘σ’ represents the standard deviation.

## C. Speckle Noise

Speckle noise is modelled as a multiplicative noise process. It is a randomly generated multiple small spot on the image (Czerwinski, Jones, and O’Brien, n.d.) (Maity et al. 2015). So, if ‘I’ is the original image, then the resultant image S will be a multiplicative noise model and can be represented in equation (4) as,

$$S = I + n * I \tag{4}$$

Where, 'n' represents uniformly distributed noise with mean 0 and variance v. Variance v value ranges from 0 to 1.

The effect of environmental factors during image acquisition is the main cause of speckle noise (Maity et al. 2015). The image with this noise will have a low contrast and thus need to be pre-processed.

## D. Poisson Noise

Poisson noise is a signal dependent noise also known as photon/shot noise and. The number of photons N measured at a given location (pixel) sensor element over a time interval t is described by the discrete probability distribution (Boyat and Joshi 2015; Bovik 2010).

$$P_r(N = K) = \frac{e^{-\lambda t}(\lambda t)^k}{k!} \qquad (5)$$

where λ is the expected number of photons per unit time interval, which is proportional to the incident scene irradiance as given in equation (5). This is a standard Poisson distribution with rate parameter λt, that corresponds to the expected incident photon count. The uncertainty described by this distribution is known as photon noise. Photon noise is signal dependent and its standard deviation grows with the square root of the signal (Boyat and Joshi 2015; Bovik 2010; Kervrann and Trubuil, n.d.).

## Noise Reduction Filters

As a part of image enhancement, restoration of the degraded image is done through various noise filters (Gonzalez 2009) (Dougherty 2009). This section is focused on the characteristics of 4 filters namely Mean, Median, Gaussian, and Poisson which were considered for this study.

## A. Mean Filter

Mean filter is a linear filter which works by replacing the value of each pixel with the average value of all the neighbouring pixels (Gonzalez 2009).

$$h[i,j] = \frac{1}{M} \sum_{(k,l)\in N} f[k,l] \qquad (6)$$

Where, N is the neighbourhood & M represents the total number of pixels in the N as given in equation (6). This helps to eliminate the unrepresented pixel values.

## B. Median Filter

A non-linear filter which replaces each pixel value with the median value of the neighboring pixel (Pitas and Venetsanopoulos 1990) (Ma and Nie 2018) (Zhu and Huang 2012). It is represented by the following equation (7):

$$y[m,n] = \text{Median}\{x[i,j],(i,j)\,\varepsilon\, w\} \tag{7}$$

Median filter works by sorting the pixels (based on their gray values) in ascending order and choosing the median value for the neighbourhood 'w' in the image as illustrated in fig 1.

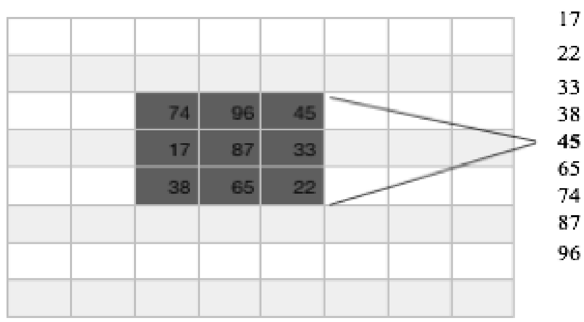



**Fig. 1 Illustration of Median Filter. A sample calculation of the median value identification from the 3x3 matrix is given. From (17,22,33,38,45,65,74,87,96) the median value of the image is identified to be 45**

## C. Gaussian Filter

It is a linear, non-uniform low pass filter which uses the gaussian function to blur or smoothen the image (Gonzalez 2009). Though it reduces the noise, it may also remove some details in the image. The degree of smoothing in the gaussian filter is determined by its standard deviation (Dougherty 2009) (Satpathy, Pradhan, and Sharma 2015). Gaussian filters work by 'weighted average' with more weight given to the central pixel and lesser weights to its neighbouring pixels.

## D. Wiener Filter

Wiener filter is a non adaptive filter which uses statistical comparison to denoise the image (Kumar and Nachamai 2017). The Wiener filter uses the least-square principle, i.e. the filter minimises the mean-squared error (MSE) between the actual and the desired image (Masoomi et al. 2019).

The MSE is calculated using equation (8):

$$w(f_1, f_2) = \frac{H * (f_1, f_2) S_{xx}(f_1, f_2)}{|H(f_1, f_2)| 2 S_{xx}(f_1 f_2) + S_{\eta\eta}(f_1 f_2)} \quad (8)$$

## Parameters for Measuring Filter Performance

Quality of an image is essential for medical diagnosis. In this paper, Image quality is estimated by parameters like Peak signal to noise ratio (PSNR), Mean square error (MSE), Normalised correlation coefficient (NCC) and Normalised Absolute Error (NAE).

### A. Peak Signal to Noise Ratio (PSNR)

PSNR calculates the ratio between the original and processed image (“Peak Signal-to-Noise Ratio as an Image Quality Metric - National Instruments” 2011; Biswas and Roy 2017). Higher the PSNR value represents the better quality of the image. PSNR is represented in equation (9).

$$\mathrm{PSNR} = 20 \log_{10}\left(\frac{\mathrm{N}}{\mathrm{MSE}}\right) \mathrm{dB} \quad (9)$$

Where, N is the maximum possible pixel value of the image, MSE is the mean square error.

### B. Mean Square Error (MSE)

MSE is an average of the squared error between the original and the processed image. Minimum value of MSE given in equation (10) indicates low error rate and high quality of the image (Biswas and Roy 2017).

$$\mathrm{MSE} = \frac{1}{\mathrm{MN}} \sum_{i=1}^{M} \sum_{j=1}^{N} [g(i, j) - f(i, j)]^2 \quad (10)$$

Where, the number of rows and columns in the input images are represented by M and N, ‘g’ is the noise image and ‘f’ is the filtered image.

### C. Normalised Correlation Coefficient (NCC)

Correlation helps to quantify the similarities between two digital images. If the NCC measurement tends to be closer to 1, then the image is considered to be of a good quality. It is computed using the following equation (11).

$$NCC = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} [f(i,j) \cdot f'(i,j)]}{\sum_{i=1}^{M} \sum_{j=1}^{N} (f(i,j))^2} \quad (11)$$

### D. Normalised Absolute Error (NAE)

Normalised absolute error should be minimal in order to reduce the difference between the original and the processed image. It is calculated using equation (12).

$$NAE = \frac{\sum_{i=1}^{M} \sum_{j=1}^{N} |[f(i,j) \cdot f'(i,j)]|}{\sum_{i=1}^{M} \sum_{j=1}^{N} |f(i,j)|} \quad (12)$$

All analyses are conducted using the SPSS tool for the experiment. Descriptive statistics (Mean, Standard deviation, Standard Error) are carried out for various filtering techniques. The independent variables are the maximum possible pixel value of the image, weighted average of the pixel, median value for the neighbourhood while the dependent variable is intensity of every pixel in the image. Independent t-test was performed to compare the performance of the techniques. Based on the analysis done it has been proved that the MSE value of the median filter is lesser.

## Result

### A. Salt and Pepper Noise

All four filters were used to reduce the salt & pepper noise on abdominal CT images based on the four parameters. Fig 2 and Table 1 shows the average performance of various filters for salt & pepper noise on 100 CT images.

**Table 1 Performance of Mean, Median, Wiener and Gaussian filters on Salt & Pepper Noise over MSE, PSNR, NCC and NAE parameters (average of 100 CT Images). It is inferred that median filter MSE & NAE (error value) are less compared to other filters**

| Parameters / Filters | MSE | PSNR | NCC | NAE |
|---|---|---|---|---|
| **Mean** | 180.73 | 25.57 | 0.9550 | 0.2576 |
| **Median** | 27.13 | 33.83 | 0.9733 | 0.0534 |
| **Wiener** | 284.33 | 23.60 | 0.9384 | 0.2572 |
| **Gaussian** | 164.16 | 26.00 | 0.9489 | 0.2615 |

From Table 1, it can be seen that the Median filter has the minimum MSE, Maximum PSNR, Closest NCC value to 1 and minimum NAE parameters. MSE error of 27.13 was obtained in using the median filter comparatively lower than the other filters. Similarly, NAE was obtained to be 0.0534 which is lower than other 3 filters. Minimum error values confirm the high removal of noise and more information gain in the abdominal CT image of salt and pepper noise. So, it can be concluded from the obtained quality parameter values that the Median filter has maximum efficiency for the salt and pepper noise.

From Fig 2(a), 2(b), 2(c), 2(d) & 2(e), it was observed that the salt and pepper noise is in the form of small grains. The noise in the CT image to be removed as a preprocessing step for applying any image processing technique. Fig 2(c) shows that the median filter removed the maximum of the salt and pepper noise of the abdominal CT image.

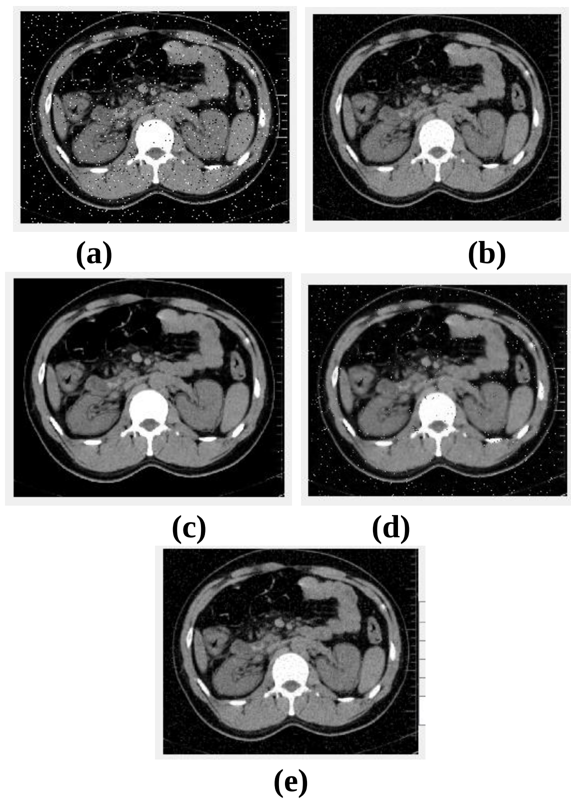



**Fig. 2 (a) Sample Salt & Pepper Noise induced in CT image; (b): Reduction of salt & Pepper noise using Mean filter; (c) Reduction of salt & Pepper noise using median Filter; (d) Reduction of salt & Pepper noise using wiener Filter; (e) Reduction of salt & Pepper noise using Gaussian Filter**

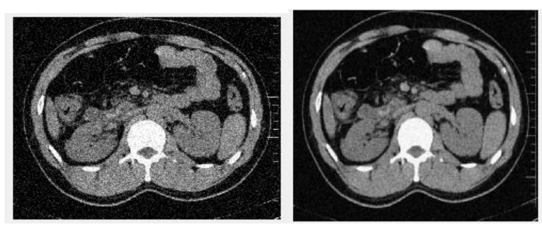
## B. Gaussian Noise

From table 2, it was observed that the Mean, Median, Wiener and Gaussian filters were used on CT abdominal images to reduce the gaussian noise. The Median filter had comparatively a minimum MSE of 102.090 and minimum NAE of 0.2718 value. Whereas, the Wiener filter has a higher PSNR value of 29.142 and correlation factor value of NCC close to 1. In any case, the application of filtering techniques would insist in error reduction quality parameters for removal of noise than other performance metrics. Based on this, the median filter performs significantly better in removing gaussian noise.

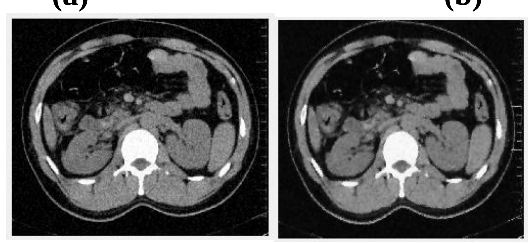
**Table 2 Performance of Mean, Median, Wiener and Gaussian filters on Gaussian Noise (average of 100 CT Images)**

| Parameters / Filters | MSE | PSNR | NCC | NAE |
|---|---|---|---|---|
| **Mean** | 187.853 | 25.408 | 0.9488 | 0.4851 |
| **Median** | 102.090 | 28.050 | 0.9674 | 0.2718 |
| **Wiener** | 137.682 | 29.142 | 0.9725 | 0.4701 |
| **Gaussian** | 186.814 | 25.439 | 0.9425 | 2.4073 |

From Fig 3(a), 3(b), 3(c), 3(d) & 3(e), it was observed that the gaussian noise is in the form of small grains. The gaussian noise in the CT image to be removed as a preprocessing step for applying any image processing technique. Fig 3(c) & 3(d) shows that both median filter and wiener filter removed the maximum of the gaussian noise of the abdominal CT image.



**(a)** **(b)**



**(c)** **(d)**

**(e)**

**Fig. 3 (a) Sample Gaussian Noise induced in the CT Image; (b) Reduction of Gaussian Using Mean Filter; (c)Reduction of Gaussian noise using Median Filter; (d) Reduction of Gaussian noise using wiener Filter; (e) Reduction of Gaussian noise using Gaussian Filter**

## C. Speckle Noise

From Table 3, it was observed that the performance of various filters on CT images for reducing the speckle noise shows that the Wiener filter has low MSE, high PSNR, and NCC value close to 1 when compared with other filters. However, the Median filter had the lowest NAE value. The NAE of the Wiener filter was the second lowest when compared with the Mean and the Gaussian Filters and the difference between the NAE of the Median and Wiener filters was very low (0.008).

**Table 3 Performance of Mean, Median, Wiener and Gaussian filters on Speckle Noise (average of 100 CT Images)**

| Parameters / Filters | MSE | PSNR | NCC | NAE |
|---|---|---|---|---|
| **Mean** | 80.2512 | 29.1886 | 0.9393 | 0.1176 |
| **Median** | 42.4118 | 31.8915 | 0.9579 | 0.0923 |
| **Wiener** | 31.2323 | 33.3134 | 0.9596 | 0.1002 |
| **Gaussian** | 85.6004 | 28.9496 | 0.9334 | 0.1235 |

From Fig 4(a), 4(b), 4(c), 4(d) & 4(e), it was observed that the speckle noise is in the form of small grains. The speckle noise in the CT image is to be removed as a preprocessing step for applying any image processing technique. Fig 4(d) shows that the Wiener filter removed the maximum of the speckle noise of the abdominal CT image.

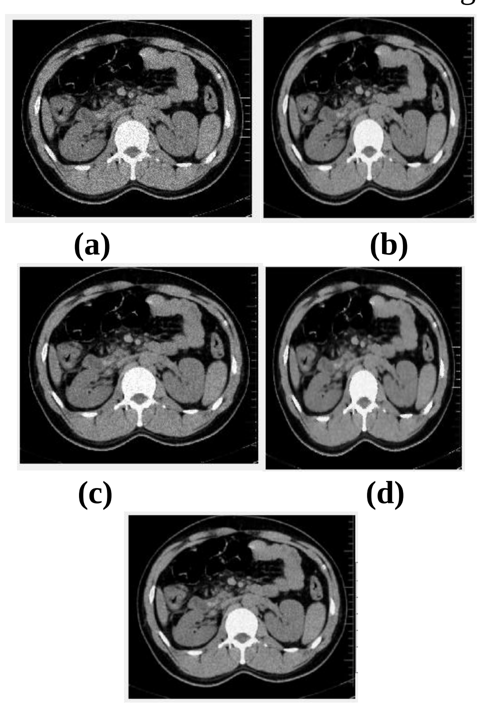



**Fig. 4 (a) Sample Speckle Noise induced in the CT Image; (b) Reduction of Speckle noise using Mean Filter; (c) Reduction of Speckle noise using Median Filter; (d) Reduction of Speckle noise using Wiener Filter; (e) Reduction of Speckle noise using Gaussian Filter**

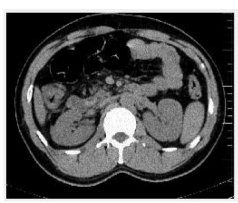
### D. Poisson Noise

Reduction of Poisson noise on the abdominal CT images are measured using the MSE, PSNR, NCC and NAE parameters. From Table 4, it can be inferred that the Wiener filter has the lowest MSE, high PSNR and NCC value close to 1 when compared with other 3 filters. The Median filter has the NAE parameter closest to 1 and the Mean filter shows a minimum NAE value. However, there is only a marginal difference of 0.009 between the NAE value of the Median and Wiener filter.

**Table 4 Performance of Mean, Median, Wiener and Gaussian filters on Poisson Noise (average of 100 CT Images)**

| Parameters / Filters | MSE | PSNR | NCC | NAE |
|---|---|---|---|---|
| **Mean** | 73.3062 | 29.6300 | 0.9478 | 0.1081 |
| **Median** | 29.2830 | 33.5315 | 0.9696 | 0.0850 |
| **Wiener** | 20.8458 | 35.0598 | 0.9761 | 0.0943 |
| **Gaussian** | 53.2171 | 30.9985 | 0.9558 | 11.5481 |

From Fig 5(a), 5(b), 5(c), 5(d) & 5(e), it was observed that the poisson noise is in the form of small grains. The poisson noise in the CT image to be removed as a preprocessing step for applying any image processing technique. Fig 5(d) shows that the Wiener filter removed the maximum of the poisson noise of the abdominal CT image.



**(a)** **(b)**

**(c)** **(d)**

**(e)**

**Fig. 5 (a) Sample Poisson Noise induced in the CT Image; (b) Reduction of Poisson noise using Mean Filter; (c) Reduction of Poisson noise using Median Filter; (d) Reduction of Poisson noise using Wiener Filter;(e) Reduction of Poisson noise using Gaussian Filter**

Table 5 shows the MSQE, PSNR, NCC and NAE values for various filters. When the mean filter is used, the mean MSQE is 130.536 (129.165-131.907), the mean PSNR is 27.450 (27.368-27.532), the mean NCC is 0.948 (0.947-0.949) and the mean NAE is 0.242 (0.235-0.249). When the median filter is used, the mean MSQE is 50.228 (49.741-50.715), the mean PSNR is 31.827 (31.775-31.879), the mean NCC is 0.967 (0.965-0.969) and the mean NAE is 0.126 (0.119-0.132). When the Wiener filter is used, the mean MSQE is 118.523 (117.480-119.567), the mean PSNR is 30.279 (29.110-31.448), the mean NCC is 100.052 (-95. 241-295.345) and the mean NAE is 0.230 (0.223-0.238). When the Gaussian filter is used, the mean MSQE is 122.448 (120.905-123.990), the mean PSNR is 27.847 (27.757-27.938), the mean NCC is 0.945 (0.944-0.946) and the mean NAE is 3.585 (-2.082-9.252).

**Table 5 MSQE, PSNR, NCC, and NAE values for the Mean (1), Median (2), Wiener (3), and Gaussian filters (4)**

| | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|
| Measure | FILTER | Mean | Std. Error | Lower Bound | Upper Bound |
| MSQE | 1 | 130.536 | .697 | 129.165 | 131.907 |
| | 2 | 50.228 | .248 | 49.741 | 50.715 |
| | 3 | 118.523 | .531 | 117.480 | 119.567 |
| | 4 | 122.448 | .785 | 120.905 | 123.990 |
| PSNR | 1 | 27.450 | .042 | 27.368 | 27.532 |
| | 2 | 31.827 | .027 | 31.775 | 31.879 |
| | 3 | 30.279 | .595 | 29.110 | 31.448 |
| | 4 | 27.847 | .046 | 27.757 | 27.938 |
| NCC | 1 | .948 | .001 | .947 | .949 |
| | 2 | .967 | .001 | .965 | .969 |
| | 3 | 100.052 | 99.336 | -95.241 | 295.345 |
| | 4 | .945 | .001 | .944 | .946 |
| NAE | 1 | .242 | .004 | .235 | .249 |
| | 2 | .126 | .003 | .119 | .132 |
| | 3 | .230 | .004 | .223 | .238 |
| | 4 | 3.585 | 2.882 | -2.082 | 9.252 |

The first column in Table 6 shows the difference in the means of the 2 groups. An asterisk in the mean difference column indicates whether the difference is statistically significant. Statistical significance can also be observed in the 3rd column of Table 6. The standard error of the difference between the two means of the groups is shown in the 2nd column of Table 6.

**Table 6 Mean differences, standard deviation, and p values of the Mean (1), Median (2), Weiner (3), and Gaussian filters (4)**

| Measure | (I) FILTER | (J) FILTER | Mean Difference (I-J) | Std. Error | Sig.[b] |
|---|---|---|---|---|---|
| MSQE | 1 | 2 | 80.308* | .668 | .000 |
| | | 3 | 12.012* | .915 | .000 |
| | | 4 | 8.088* | .242 | .000 |
| | 2 | 1 | -80.308* | .668 | .000 |
| | | 3 | -68.296* | .491 | .000 |
| | | 4 | -72.220* | .761 | .000 |
| | 3 | 1 | -12.012* | .915 | .000 |
| | | 2 | 68.296* | .491 | .000 |
| | | 4 | -3.924* | 1.018 | .001 |
| | 4 | 1 | -8.088* | .242 | .000 |
| | | 2 | 72.220* | .761 | .000 |
| | | 3 | 3.924* | 1.018 | .001 |
| PSNR | 1 | 2 | -4.377* | .042 | .000 |
| | | 3 | -2.829* | .595 | .000 |
| | | 4 | -.398* | .021 | .000 |
| | 2 | 1 | 4.377* | .042 | .000 |
| | | 3 | 1.548 | .595 | .058 |
| | | 4 | 3.980* | .047 | .000 |
| | 3 | 1 | 2.829* | .595 | .000 |
| | | 2 | -1.548 | .595 | .058 |
| | | 4 | 2.432* | .596 | .000 |
| | 4 | 1 | .398* | .021 | .000 |
| | | 2 | -3.980* | .047 | .000 |
| | | 3 | -2.432* | .596 | .000 |
| NCC | 1 | 2 | -.019* | .001 | .000 |
| | | 3 | -99.104 | 99.336 | 1.000 |
| | | 4 | .003* | .000 | .000 |
| | 2 | 1 | .019* | .001 | .000 |
| | | 3 | -99.085 | 99.336 | 1.000 |
| | | 4 | .022* | .001 | .000 |
| | 3 | 1 | 99.104 | 99.336 | 1.000 |
| | | 2 | 99.085 | 99.336 | 1.000 |
| | | 4 | 99.107 | 99.336 | 1.000 |
| | 4 | 1 | -.003* | .000 | .000 |
| | | 2 | -.022* | .001 | .000 |
| | | 3 | -99.107 | 99.336 | 1.000 |

| Measure | (I) FILTER | (J) FILTER | Mean Difference (I-J) | Std. Error | Sig.[b] |
|---|---|---|---|---|---|
| NAE | 1 | 2 | .116* | .004 | .000 |
| | | 3 | .012* | .002 | .000 |
| | | 4 | -3.343 | 2.882 | 1.000 |
| | 2 | 1 | -.116* | .004 | .000 |
| | | 3 | -.105* | .004 | .000 |
| | | 4 | -3.459 | 2.882 | 1.000 |
| | 3 | 1 | -.012* | .002 | .000 |
| | | 2 | .105* | .004 | .000 |
| | | 4 | -3.355 | 2.882 | 1.000 |
| | 4 | 1 | 3.343 | 2.882 | 1.000 |
| | | 2 | 3.459 | 2.882 | 1.000 |
| | | 3 | 3.355 | 2.882 | 1.000 |

In Fig. 6 Wiener filter is found to perform equally well with median filter in handling a variety of noises. Wiener filter is found to have mean (0.97) values slightly above the other filtering schemes. High standard deviation is observed while reducing the speckle noise, indicating that the Wiener filtering poses challenges in dealing with granular pixels.

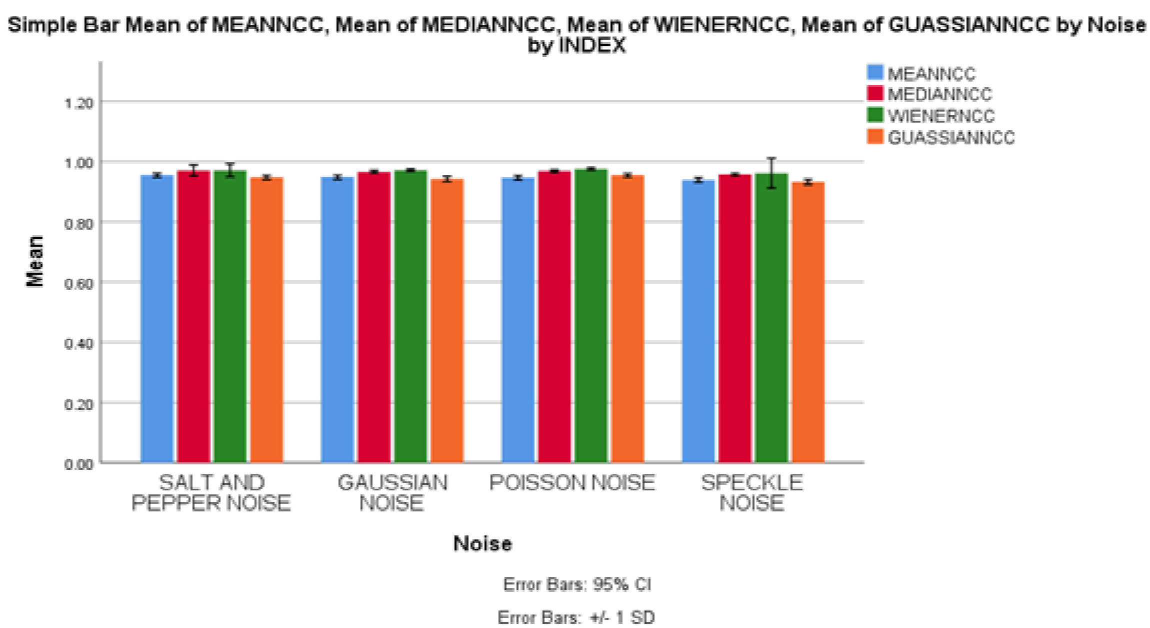



**Fig. 6 Efficiency of different filtering methods depending on different noises. Wiener filter is found to perform equally well with median filter in handling a variety of noises. Wiener filter is found to have mean (0.97) values slightly above the other filtering schemes. High standard deviation is observed while reducing the speckle noise indicating that the Wiener filtering pose challenges in dealing with granular pixels.The X axis in the graph represents different noises and Y axis represents mean value of normalized cross correlation values with ±1 SD and 95 % confidence interval**

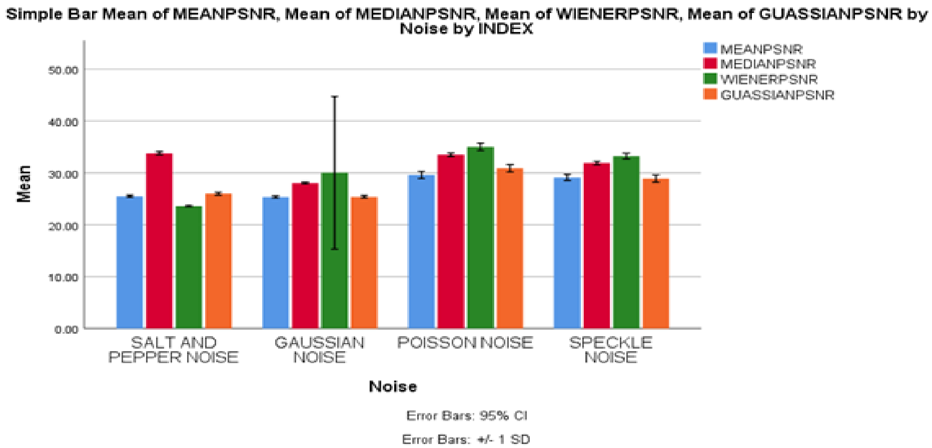



**Fig. 7 Efficiency of different filtering methods depending on PSNR values while handling different noises. It can be observed that the Wiener filters exhibit poor efficiency in handling rapid variation of pixels due to salt and pepper noise. The Wiener filter has better performance in dealing with the Gaussian, Poisson and speckle noise. Large standard deviation (23.6) conveys that the Wiener filters possess challenges in handling the noise which follows Gaussian distribution but still perform better than other filtering schemes. High mean values of Weiner in handling Poisson (35.05) and Speckle (33.31) noise indicate that the Wiener filter can handle the noise caused due to poor lighting effect and also granular in nature. The X axis in the graph represents different noises and the Y axis represents mean value of PSNR with ±1 SD and 95 % confidence interval**

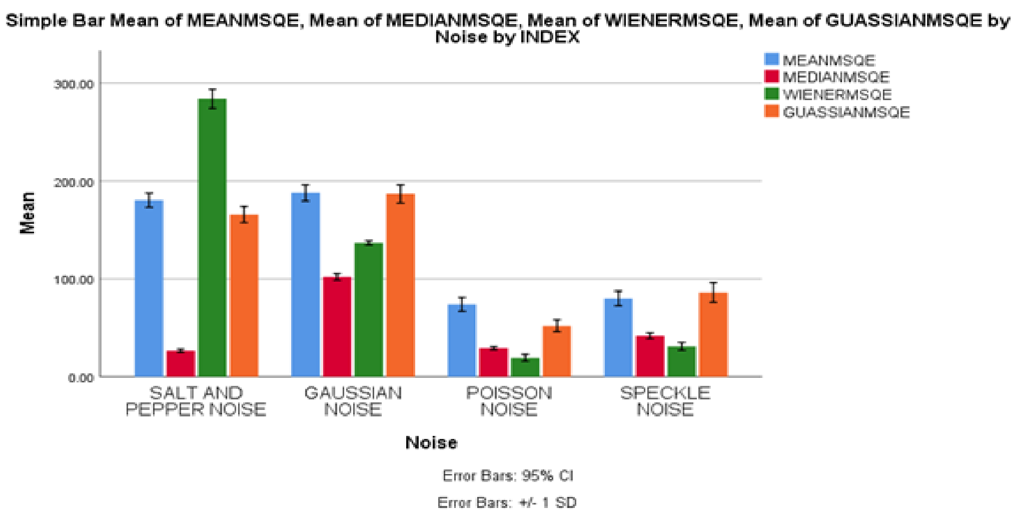



**Fig. 8 Efficiency of different filtering methods depending on mean square error values for handling various noises. Lower MSQE mean value of the median filter shows its effectiveness in handling salt and pepper noise (27.12) and Gaussian noise (102.08). Wiener filters perform better than median filters while handling Poisson noise and speckle noise. From this graph it can be observed that the Wiener filter is capable of handling the distortion caused due to the Poisson effect (20.84) and granular pixels (31.23). The X axis in the graph represents different noises and Y axis represents the mean value of MSQE with ±1 SD and 95 % confidence interval**

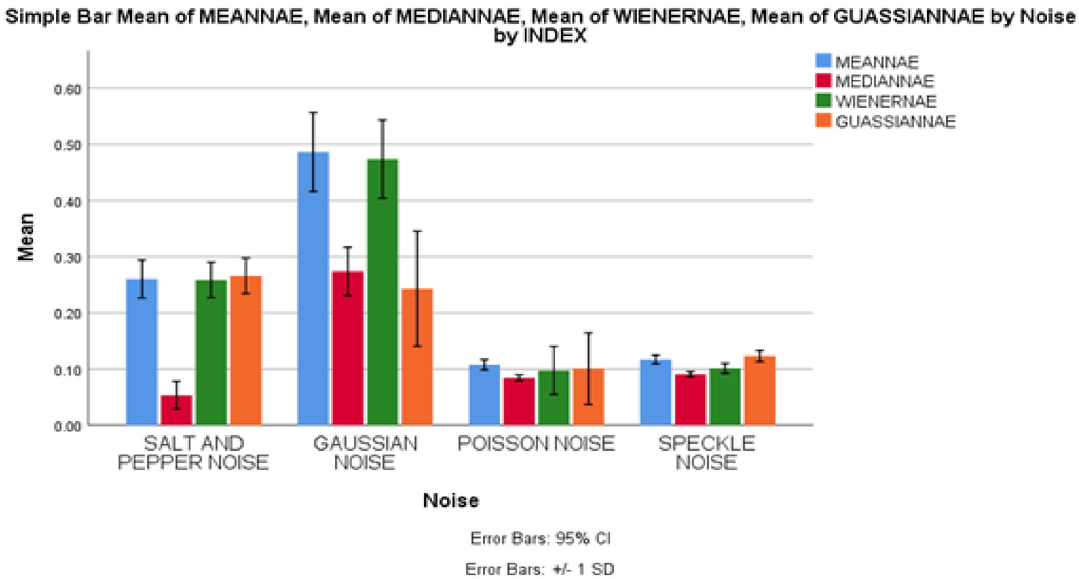



**Fig. 9 Efficiency of different filtering methods depending on normalized absolute error values for handling various noises. The median and Wiener filters are found to perform significantly better than mean and Gaussian filters in handling salt and pepper noise, Poisson noise and speckle noise. The Gaussian filter is capable of modeling the noise since it follows a Gaussian distribution with mean value 0.25 compared to the mean filter (0.485), Median (0.271) and Wiener filter (0.470) comparatively. The X axis in the graph represents different noises and the Y axis represents mean value of MSQE with ±1 SD and 95 % confidence interval**

In this overall analysis, it was observed that the median filter shows higher performance in the reduction of salt & pepper noise. Median and Wiener filters can be effective against Gaussian noise. Whereas, the Wiener filter shows significantly better performance for speckle and poisson noise.

## Discussion

Based on the statistical analysis, the following outcomes were discussed for abdominal CT images. It is observed that the performance of the median filter was more suitable to reduce the salt and pepper noise which is also evident from (Kumar and Nachamai 2017). Whereas, for Gaussian Noise, the Wiener filter has got the highest PSNR & better NCC values when compared with other filters but the median shows low MSE & better NAE values. Based on table 2, it can be seen that the NAE value of Wiener is also close to the Median Filter and the MSE value of Wiener is the next lowest after Median. However, the difference of NAE between Median and Weiner is very low (0.008 for Speckle and 0.009 for Poisson noise).

There were few researches using different filtering techniques for enhancing the medical image quality like (Rakhshanfar and Amer 2018) achieved an average PSNR value of 32.97 in low frequency images. (Rakhshanfar and Amer 2018, 2016) proposed an LF noise removal using WGN filter performs better as it preserves the edges with average PSNR value of 32.99. (Khan, Arya, and Pattanaik 2010) proposes an image enhancement technique using partial masking and conservetive smoothing for removal of salt and pepper noise with PSNR value of 29.26. (Khan, Arya, and Pattanaik 2010; Nair and Reji 2011) proposes directional weighted filtering techniques to improve performance of corrupted salt and pepper noise in MRI brain images. (Marudhachalam and Ilango 2012) proposed a fuzzy hybrid filtering method for removal of random noise from various medical images. The quality of noise reduction is measured using PSNR's highest value of 42.1 for a variance of random noise of 0.1606.

Noise removal techniques play an important role in medical image processing as it helps in improving the quality of images. There are few filters that are frequently used such as Median, Mean, Gaussian etc. The need to identify the best filtering technique is an essential step in medical image processing. The limitations of filtering techniques are not being able to preserve edges efficiently, which is difficult in analytical treatment.

## Conclusion

This paper compares the efficiency of four spatial filters namely: Mean, Median, Gaussian and Wiener filters over four parameters namely MSE, PSNR, NCC and NAE in denoising the 100 abdominal CT images. It can be concluded that both Median and Wiener filters will be effective against reducing the Gaussian Noise. For both Speckle and Poisson Noise, the Wiener filter shows a significant efficiency in MSE, PSNR and NCC parameters except for the NAE value which is better for the Median filter. It can be concluded that the Median filter is best suited for Salt & Pepper noise and the Wiener filter can be used to remove the Speckle and Poisson noise.

## Declarations

## Conflict of Interests

Authors have no conflicts of interest in this manuscript.

## Author Contribution

Author RM. was involved in data collection, data analysis, and manuscript writing. Author SPC was involved in conceptualization, data validation, and critical review of manuscripts. Author KG was involved in interpreting Results and Discussion and Document editing. Author RA was involved in interpreting Results and Discussion and Document editing.

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