

Performance Analysis of Different Restoration Techniques for Degraded 3D Cervical Spine MRI Image

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In the proposed work, noise models such as Salt & Pepper, Gaussian and Poisson are considered in order to corrupt the image. Image restoration is still a challenging task to recover an original image using a degradation and restoration model. In the paper, Gaussian, Average and Wiener linear image restoration techniques are used to recover the original MRI image. Median filter, Min and Max non-linear filters are also used to obtain uncorrupted image in the paper. Mean square error (MSE), Peak Signal to Noise Ratio (PSNR) and Cross Correlation (CC) performance analysis criteria are used to compare different restoration techniques so that better performance in a clinical diagnosis can be achieved. In the paper it can be found that Wiener filter with 5 x 5 window for Gaussian, speckle and Poisson noise provides best performance in terms of MSE and PSNR. Also, median filter with 5 x 5 window gives better accuracy of results to restore 3D salt & pepper noised image in terms of MSE and CC.

Keywords: Image degradation; Image restoration; Linear and Nonlinear filter; MRI image; MSE; PSNR.

The Image processing takes an image as an input and provides uncorrupted output image or original image information. In the present scenario, digital image processing is used in various fields such as medical imaging processing for diagnosis of diseases, face recognition for security purposes and resource exploration¹. There are several degradation sources such as noise and blur presented in the available literature which may corrupt the image^{2,5,7,8,12}. The process of recovering an image that has been degraded by a son degradation process is known as Image Restoration. In the field of engineering, digital image processing introduced a different kind of

image restoration methods to recover original scene from degraded observations. The noise removal method should be applied in accurate manner in order to obtain precise image in medical image processing². Various restoration techniques exist both in spatial and frequency domain. In the proposed work, motion, out of focus and environmental turbulence blurs are considered in degradation of 3D cervical spine MRI Image. In the paper Salt and Pepper, Gaussian, Speckle and Poisson noises are added in order to corrupt image. The linear (Gaussian filter, Average filter, Poisson filter) and nonlinear (Median, Min and Max filter) restoration techniques both are

used to obtain precise image so that uncorrupted image can be used to get correct observations for the given application in medical image process. In the paper, MSE, PSNR and CC performance analysis criterions are used for selection of best filter for a particular type of noise model to recover noiselessly and de blurred image and thus to enhance performance of restoration techniques.

Image Degradation Models

Image acquisition depends on the quality of sensing elements, transmission media and environmental conditions such as atmospheric disturbance, humidity, light, and temperature etc. In the proposed work, degradation of image is also done by motion blur, out-of-focus and environmental turbulence blurs. Motion blur is the visible line of a different colour of moving objects³. It is the most widely recognized corruption types found in the customer photography. In most cases, the out of focus blur caused by a system with a circular aperture. An Image formed by connecting the stage of optical system analogous to a lens, selected depth of the object is aimed by the lens, but the objects at different distances are corrupted by different level calculating on their distances. The parameters on which the camera focus depends on focal distance, wavelength of the incoming light object, object depth and aperture size⁴. This type of Long-term exposure to atmospheric distortions is commonly experienced in remote sensing and aerial imaging caused by optical turbulence and scattering and absorption by particulate results in a degraded image³. Salt and Pepper, Gaussian, Speckle and Poisson which are added in order to corrupt 3D cervical spinal MRI image and described as follows:

Salt & Pepper Noise Or Impulse Noise

This noise appears in images as black and/ or white impulse of the image. The noise is due to white and black spots which chaotically scattered gray scale images along image area. The Power Density Function for Salt & Pepper noise is given as^{5,12}:

$$P_{sp}(z) = \begin{cases} P_p & \text{for } z=p \\ P_s & \text{for } z=s \\ 0 & \text{otherwise} \end{cases}$$

The basic steps which are used to add salt and pepper noise into RGB and Gray Scale image

are given as:

1. First color image is converted into monochrome image.
2. Random values will be generated by “randn” function for the given matrix size within the specified range. Consider an image matrix of size 4x3 image matrix as:

4	10	4
7	8	4
10	0	5
3	10	9

3. The random matrix 4x3 is generated with range 0 to 10. Let random matrix be:

237	107	166
234	95	162
239	116	169
56	126	89

4. If there is ‘0’ value in the random matrix this pixel value is now replacing with zero or black. After that, black pixel is entered in image matrix.

237	107	166
234	95	162
239	0	169
56	126	89

5. Similarly image matrix contains white pixel by replacing pixel value ten with pixel value 255 if random matrix contains pixel value 10. Finally, the image matrix become,

237	255	166
234	95	162
255	0	169
56	126	89

The effect of the addition of this noise in RGB and Gray Scale Image is shown in Figure1.

Gaussian Noise

Gaussian noise is one of the most occurring noise and also called additive noise. In this noise certain distribution is added to each pixel in order to modify it^{2,12}. Whenever this noise appears, then receiver interprets received sample value y(k) at the kth sample time as the sum of noise-free component y₀(k), i.e., the sample value

that would have been received at the k th sample time in the absence of noise and noise component $w(k)$, assumed independent of the input waveform. It can be written as:

$$y(k) = y_0(k) + w(k)$$

The noise component $w(k)$ is irregular, but assumed to be drawn at each sample time from a

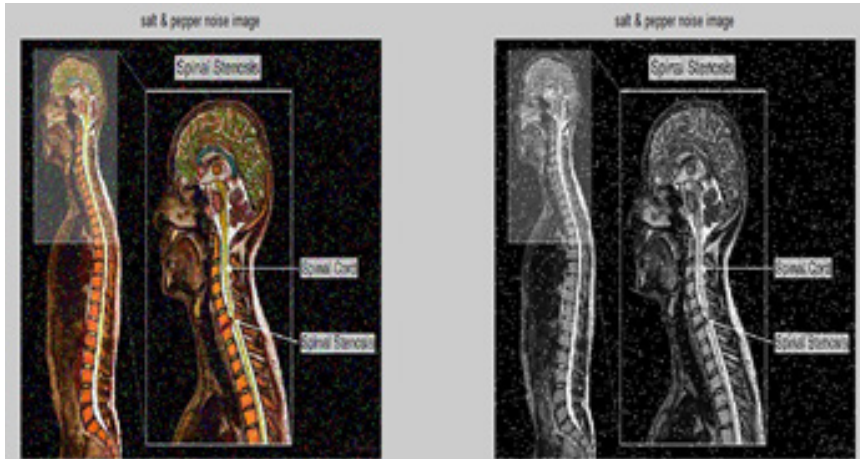


Fig. 1. RGB and Gray Scale Image Degraded by Salt & Pepper Noise with noise density 0.05

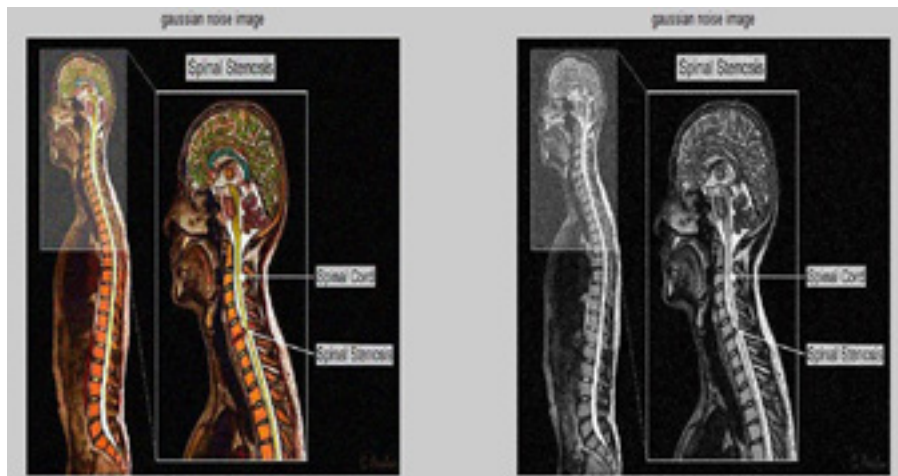


Fig. 2. RGB and Gray Scale Image Degraded by Gaussian Noise with noise variance 0.005



Fig. 3. RGB and Gray Scale Image Degraded by Speckle Noise with noise density 0.04

fixed Gaussian distribution for concreteness. And RGB and Gray Scale Image which is degraded by Gaussian Noise with noise variance 0.005 is presented in figure 2.

Speckle Noise

This noise is usually modeled by random element multiplication with pixel elements of the image⁶. The random settlement of the pixel in the image appears due to inherent characteristic of ultrasound imaging. This unknown settlement of the pixel in the image is known as speckle noise. Radical reduction in distinction resolution due to speckle noise produces a negative impact on medical imaging⁷. The speckle noise can be modelled as:

$$h(n, m) = i(n, m) * u(n, m) + \eta(n, m) \quad \dots(1)$$

Where, $h(n,m)$ is the observed image, $u(n,m)$ is the multiplicative component and $\eta(n,m)$ is the additive component of the speckle noise. Here n and m denote the axial and lateral indices of the image samples. For the ultrasound imaging, an only multiplicative component of the noise is to be considered and additive component of the noise is to be ignored. Hence, equation (1) can be modified as;

$$h(n, m) = i(n, m) * u(n, m) + \eta(n, m) \quad \dots(2)$$

Therefore, $h(n, m) = i(n, m) * u(n, m)$

The behavior of Speckle pattern depends on the number of disperse per resolution cell or disperse number density. In the figure3, speckle noise with noise density 0.04 is added to RGB and Gray Scale Image to degrade it.

Poisson Noise

When the electromagnetic waves of high energy are injected into patient’s body from its source, this noise appears due to the statistical nature of electromagnetic waves on medical instrument of imaging systems. The noise is also called as quanta (photon) noise or shot noise. This noise obeys the Poisson distribution which is given as :

$$\Pr(N = k) = (e^{-\lambda t} (\lambda t)^k) / k! \quad \dots(3)$$

Where λ is the expected number of the particles i.e. photons per unit time interval, which is proportional to the occurrence of the scene radiance. A rate parameter ‘ λt ’ is known as the standard Poisson scattering or distribution which corresponds to the expected incident photon count. The uncertainty described by this diffusion is known as photon noise. Photon noise include random electron emission which consists of Poisson distribution with mean square value⁸. Because the occurrence of the light particle count follows a Poisson scattering, it has the property that its variance is equal to its expectation that is represented by equation 4.

$$E[N] = Var[N] = \lambda t \quad \dots(4)$$

This shows that its standard deviation grows with the square root of the signal and photon noise is information or signal dependent. Photon noise variance depends on the expected photon count and is often modelled using a Gaussian distribution as:

$$N \sim N(\lambda t, \lambda t)$$

This approximation in most cases is very accurate. According to the central limit theorem, for larger particles of light count or photon count Poisson distribution approaches to Gaussian distribution and for the small particles of light counts photon distribution is dominated by other signal independent sources of random signal. The effect of Poisson noise after its addition in RGB and Gray Scale Image is presented in figure 4.

Image restoration techniques

Linear Restoration Method

In this method the original image is to be convolved with a mask. The mask represents a low-pass filter or smoothing operation which is used to restore certain type of noised images. The output of a linear operation due to the sum of two inputs is same as that of performing the operation on the inputs individually and then summing the results. Some of the linear restoration methods used to restore the captures 3D MRI image are given as:

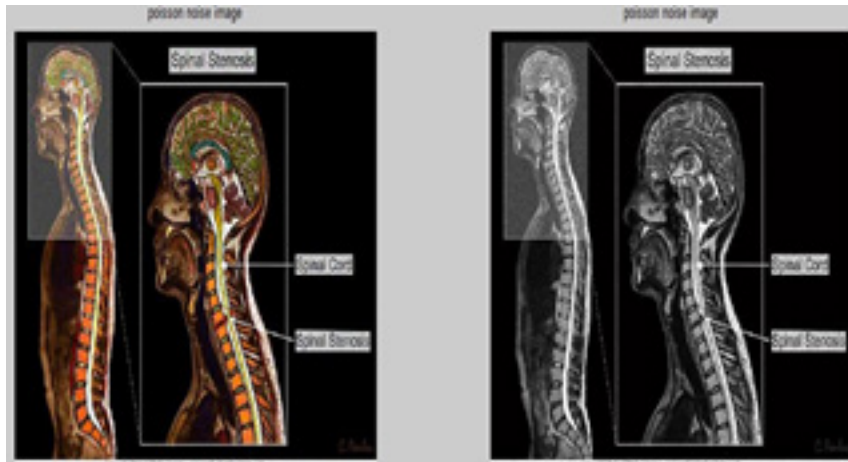


Fig. 4. RGB and Gray Scale Image Degraded by Poisson Noise

Gaussian Filter

It works by using the 2D distribution as a point-spread function. This is achieved by convolving the 2D Gaussian distribution function with the image. And to implement it steps which are used are given as:

1. Design the kernel window
2. Use formula to design 2D Gaussian kernel

$$G(x, y) = (1/2\pi\sigma^2) e^{-(x^2+y^2)/2\sigma^2}$$

For this consider the standard deviation, sigma =0.6 and the kernel size 3x3. i.e $(1/2\pi\sigma^2) = 1/2.2619$

3. The width of the kernel is X=3 and the height of the kernel is Y=3.

$$\begin{matrix} -1 & 0 & 1 \\ X=-1 & 0 & 1 \\ -1 & 0 & 1 \end{matrix}$$

and

$$\begin{matrix} -1 & -1 & -1 \\ Y = 0 & 0 & 0 \\ 1 & 1 & 1 \end{matrix}$$

4. The Gaussian kernel's dominant part (Here 0.4421) has the highest value and intensity of other element decreases the distance from the median

or dominant part increases. Now the Gaussian kernel is:

$$\begin{matrix} 0.0275 & 0.1102 & 0.0275 \\ 0.1102 & 0.4421 & 0.1102 \\ 0.0275 & 0.1102 & 0.0275 \end{matrix}$$

Convolve the kernel and the local region from an image.

$$\begin{matrix} 72 & 68 & 88 & 159 \\ 69 & 66 & 87 & 162 \\ 70 & 66 & 83 & 161 \\ 70 & 66 & 78 & 154 \end{matrix}$$

Convolve the selected part and the kernel

$$\begin{matrix} 68 & 88 & 159 & 0.0275 & 0.1102 & 0.0275 & 1.8692 & 9.7009 & 4.3706 \\ 66 & 87 & 162 & 0.1102 & 0.4421 & 0.1102 & 7.2757 & 38.4624 & 17.8585 \\ 66 & 83 & 161 & 0.0275 & 0.1102 & 0.0275 & 1.8142 & 9.1497 & 4.4256 \end{matrix}$$

Add up the values in the vector: - 1.8692+9.7009+4.3706+7.2757+38.4624+ 17.8585+ 1.8142+9.1497+4.4656=94.9269

On convolution of the local region and the Gaussian kernel gives the highest intensity value to the center part of the local region (38.4624) and the remaining pixels have less intensity as the distance from the center increases. The result obtained from the total sum is stored in the present pixel location (Intensity=94.9269) of the image.

□	□	□	□
□	□	94.9269	□
□	□	□	□
□	□	□	□

Average Filter

The filter operates on a $m \times n$ mask by taking average of all pixel values within the window and replace the center pixel value in the final image with the result. It also causes a certain amount of blurring in the image¹¹.

$$(x, y) = (1/mn) \sum_{(r, c) \in W} g(r, c)$$

...(5)

Let f_{ij} for $i, j = 1, \dots, n$, denote the pixel values in the image. Here g is used with pixel values g_{ij} to denote the output from the filter. A linear filter of size $(2m+1) \times (2m+1)$, with specified weight w_{kl} for $k, l = -m, \dots, m$, gives :

$$g_{ij} = \sum_{k=-m}^{m} \sum_{l=-m}^{m} w_{kl} f_{i+k, j+l}$$

for $i = (m+1) \dots (n-m)$

For example, if $m = 1$, then the window over which averaging is carried out is 3×3 , and

$$\begin{matrix} w_{-1,-1}f_{i-1,j-1} & w_{-1,0}f_{i-1,j} & w_{-1,1}f_{i-1,j+1} \\ w_{0,-1}f_{i,j-1} & w_{0,0}f_{i,j} & w_{0,1}f_{i,j+1} \\ w_{1,-1}f_{i+1,j-1} & w_{1,0}f_{i+1,j} & w_{1,1}f_{i+1,j+1} \end{matrix}$$

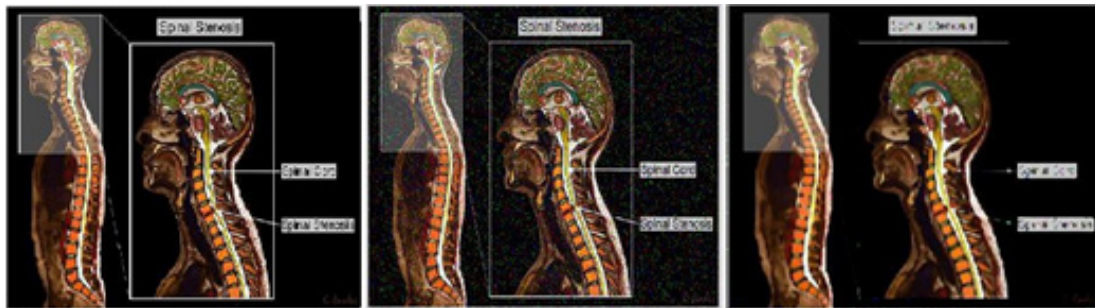


Fig. 5. (i) Input Image (ii) Salt & Pepper crashed Image (iii) Image clarified with Median 5x5 filter masks

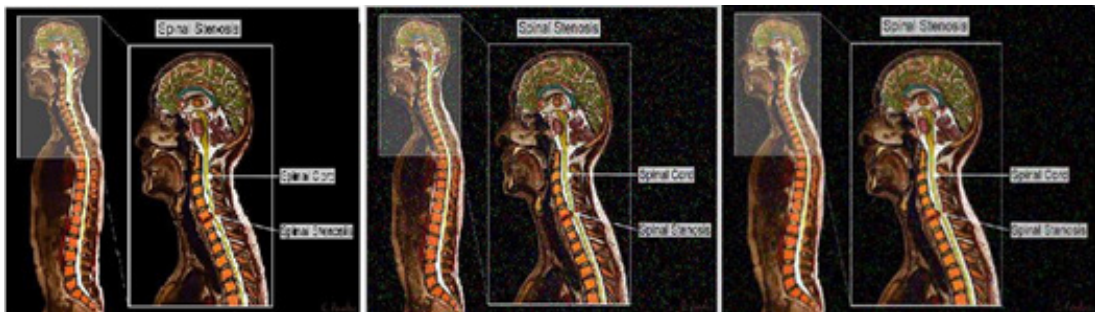


Fig. 6. (i) Input Image (ii) Salt & Pepper crashed Image (iii) Image clarified with Gaussian 5x5 filter masks

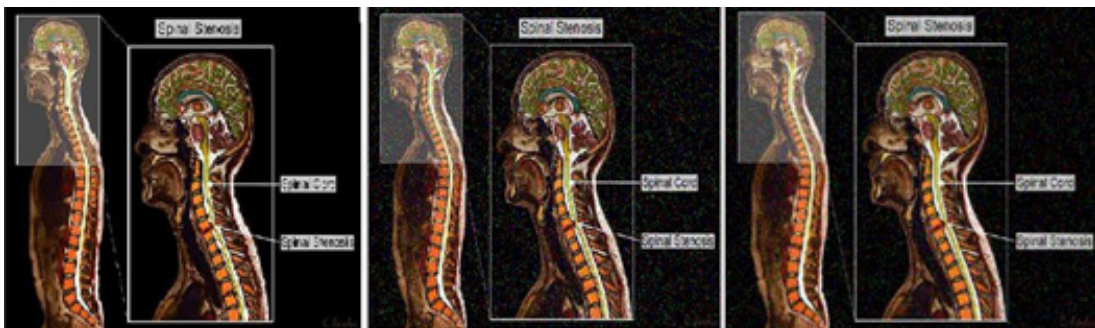


Fig. 7. (i) Input Image (ii) Salt & Pepper crashed Image (iii) Image clarified with Average 5x5 filter masks

The weights (w) can depend on i and j for full generality and result in a filter which vary across the image. Also, all the filters will have windows composed of odd numbers of rows and columns. It is possible to have even-sized windows, but there will be half-pixel displacement between the input and output images.

Wiener Filter

It is a digital filter used to adjust variable parameters obtained due to mathematical programming. This filter is applied to the degraded image to adjust the local variance of the image. By adjusting its variance means calculating the distance between random number or noisy pixel and average of those pixels centered within the mask. Smoothing of the image is totally depending upon the variance of the image. Large value of the variance results in less smoothing and small value

of the variance results in more smoothing. This type of linear filtering is more adaptive in the field of image processing as it produces better results. The following steps are used for its implementation:

1. Define a window of size $m \times n$
2. Consider matrix B with Gaussian noise.

$$B = \begin{bmatrix} 0.9361 & 1.000 & 1.000 & 0.8871 \\ 1.000 & 1.000 & 0.9184 & 1.000 \\ 0.9868 & 1.000 & 1.000 & 0.9591 \\ 0.000 & 0.8987 & 0.9400 & 1.000 \end{bmatrix}$$

Let window size be 3×3 and pad the matrix B with zeros on all sides.

48.7478	59.2645	79.7865	100.2444
57.1176	69.7512	94.9269	121.1870
57.1740	68.9526	92.2220	119.6981
47.7534	59.9750	74.1254	96.7113

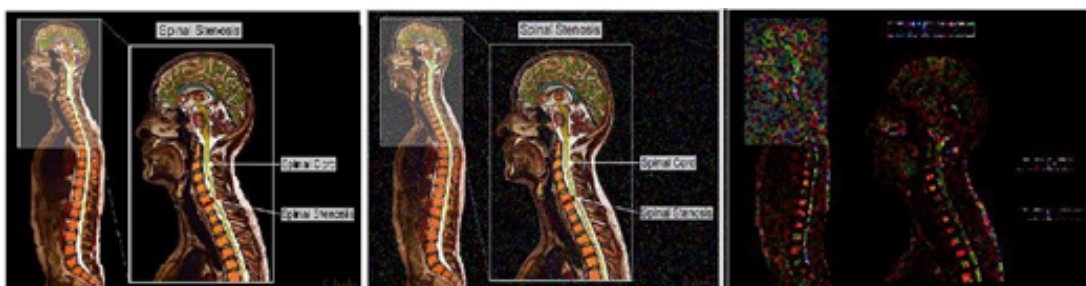


Fig. 8. (i) Input Image(ii) Salt &Pepper crashed Image (iii) Image clarified with MIN5x5 filter masks



Fig. 9. (i) Input Image (ii) Salt & Pepper crashed Image (iii) Image clarified with MAX5x5 filter masks

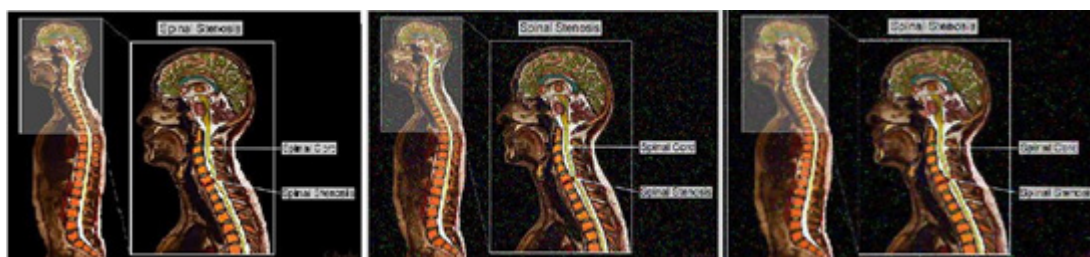


Fig. 10. (i) Input Image (ii) Salt & Pepper crashed Image (iii) Image clarified with Wiener 5x5 filter masks

0	0	0	0	0	0
0	0.9361	1.000	1.000	0.8871	0
0	1.000	1.000	0.9184	1.000	0
0	0.9868	1.000	1.000	0.9591	0
0	0.000	0.8987	0.9400	1.000	0
0	0	0	0	0	0

The local variance for the given matrix B is:

0.2394	0.2124	0.2095	0.2246
0.2169	0.009	0.0017	0.2064
0.2366	0.0939	0.0015	0.2096
0.2063	0.2309	0.2085	0.2349

3. Compute the local mean and local variance by sliding the 3x3 window

window =

0	0	0
0	0.9361	1.000
0	1.000	1.000

The variance of the overall noise is the average of the local variance Hence, variance of noise=0.1709.If (noise variance > local variance (x,y)) then Local variance (x,y)=noise variance Here,(x,y) represent the pixel positions in two dimension finally, local variance becomes:

Local mean=mean (window) =0.4373
 Local variance = mean (window²) – mean (window) ² = 0.2394

0.2394	0.2124	0.2095	0.2246
0.2169	0.1709	0.1709	0.2064
0.2366	0.1709	0.1709	0.2096
0.2063	0.2309	0.2085	0.2349

Then local mean matrix for the given matrix B

Final image = B – (noise variance / local variance) (B – local mean)

0.4373	0.6505	0.6451	0.4228
0.6581	0.9824	0.9738	0.6405
0.5428	0.8604	0.9685	0.6464
0.3206	0.5362	0.6442	0.4332



Fig. 11. (i) Input Image (ii) Gaussian crashed Image (iii) Image clarified with Median 5x5 filter masks



Fig. 12. (i) Input Image (ii) Gaussian crashed Image (iii) Image clarified with Gaussian 5x5 filter masks

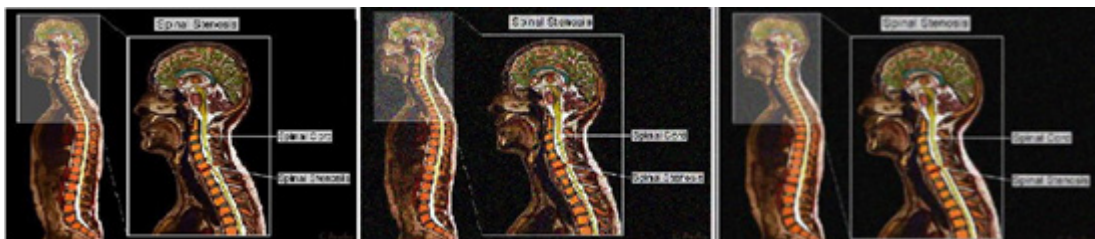


Fig. 13. (i) Input Image (ii) Gaussian crashed Image (iii) Image clarified with Average 5x5 filter masks

0.5802	0.7188	0.7105	0.5339
0.7307	0.9824	0.9738	0.7025
0.6662	0.8604	0.9685	0.7042
0.2656	0.6304	0.6975	0.5878

applications, especially removal of noise that is not additive¹⁰. Some of the nonlinear restoration methods used in the proposed work are given as:

Median Filter

It is one of the order Statistic or Rank Filter due to its nature of edge preserving. In this middle pixel value from the ordered set of values within the mxn neighborhood(W) around the reference pixel is selected^{2,4}

$$(x, y) = \text{median}\{g(r, c) | (r, c) \in W\} \dots(6)$$

Nonlinear Restoration Method

In this method, it is necessary to impose constraints such as non-negativity i.e. either positive or zero to implement spatial adaptively and recover missing spatial or frequency components at the expense of economical implementation and native convergence. Non-linear filters preserve the details of the image. Non-linear filters have many



Fig. 14. (i) Input Image (ii) Gaussian crashed Image (iii) Image clarified with MIN 5x5 filter masks

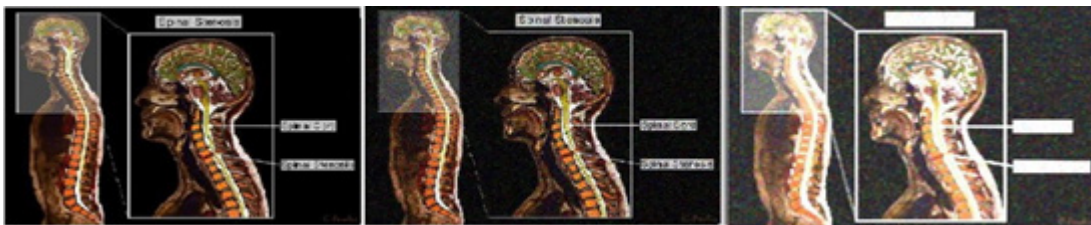


Fig. 15. (i) Input Image (ii) Gaussian crashed Image (iii) Image clarified with MAX 5x5 filter masks



Fig. 16. (i) Input Image (ii) Gaussian crashed Image (iii) Image clarified with Wiener 5x5 filter masks



Fig. 17. (i) Input Image (ii) Speckle crashed Image (iii) Image clarified with Median 5x5 filter masks

And an output value of pixel is determined by replacing the value of each corresponding pixel by the median of the neighboring pixels, rather than the mean. The mean of the extreme values of the pixels in the degraded image is more sensitive to its median. This filter has ability to preserve the edges of the image i.e contrast or sharpness of image. The image filtered with 3x3 windows still contains salt and pepper noise, but the edges are sharp. The image filtered with a larger window size contains less noise as compared to less window size. Now the implementation process used to restore the corrupted image is given as:

Let the original image with the matrix

4	6	9
2	5	3
8	1	7

Now apply padding on the image matrix.

0	0	0	0	0
0	4	6	9	0
0	2	5	3	0
0	8	1	7	0
0	0	0	0	0

Consider a mask of size 3by3. The mask can be of any size. Starting from matrix A(1,1) and place the window.

window =

0	0	0
0	4	6
0	2	5

The middle pixel value A (2, 2) will be change after sorting



Fig. 18. (i) Input Image (ii) Speckle crashed Image (iii) Image clarified with Gaussian 5x5 filter masks

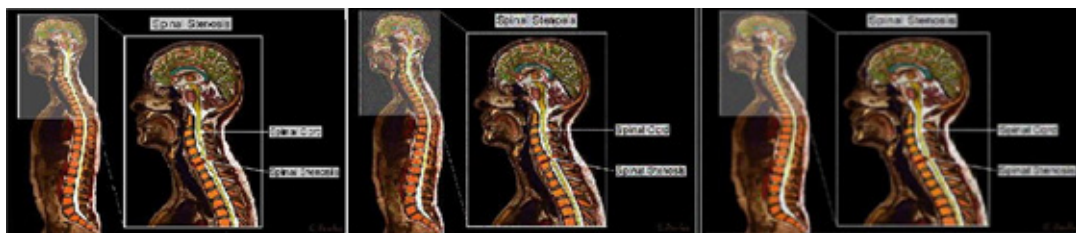


Fig. 19. (i) Input Image (ii) Speckle crashed Image (iii) Image clarified with Average 5x5 filter masks



Fig. 20. (i) Input Image (ii) Speckle crashed Image (iii) Image clarified with MIN 5x5 filter masks

Window = $\begin{matrix} 0 & 0 & 0 \\ 0 & 4 & 6 \\ 0 & 2 & 5 \end{matrix}$

After Sorting the mask matrix. Now the new matrix is

$\begin{matrix} 0 & 0 & 0 \\ 0 & 0 & 2 \\ 4 & 5 & 6 \end{matrix}$

The pixel value of the output image matrix is replaced by median 0. The value of the output pixel is found using the median of the neighboring pixels. Repeat this process until the whole matrix is replaced by the median value safter that the final output matrix is

$\begin{matrix} 0 & 3 & 0 \\ 2 & 5 & 2 \\ 0 & 2 & 0 \end{matrix}$

Minandmax filter

It works on a ranked set of pixel values. The *min* filter, also known as the zeroth percentile. The *min* filter replaces the reference pixel with the lowest value¹¹. Similarly, the *max* filter, also known as the 100th percentile filter, replaces the reference pixel within the window with the highest value. Now the following steps are used for the implementation of *max* filter to recover the original image:

Consider matrix A :

$\begin{matrix} 1 & 2 & 2 & 1 \\ 1 & 1 & 0 & 3 \\ 2 & 4 & 1 & 5 \\ 2 & 1 & 2 & 0 \end{matrix}$



Fig. 21. (i) Input Image (ii) Speckle crashed Image (iii) Image clarified with MAX 5x5 filter masks

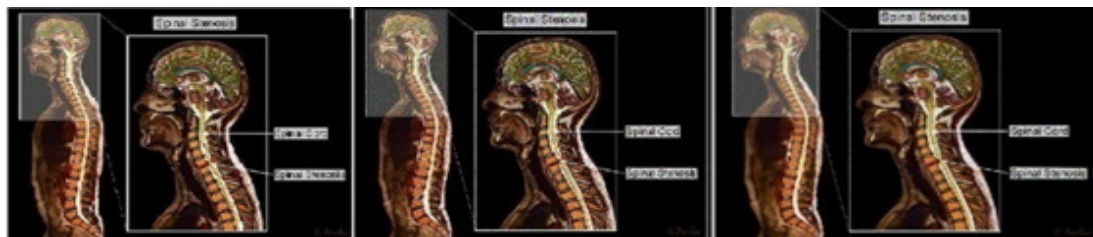


Fig. 22. (i) Input Image (ii) Speckle crashed Image (iii) Image clarified with wiener 5x5 filter masks

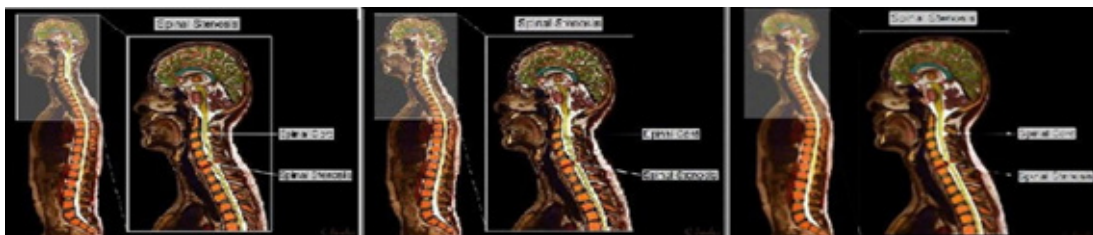


Fig. 23. (i) Input Image (ii) Poisson crashed Image (iii) Image clarified with Median 5x5 filter masks

Pad matrix with zeros and matrix A will be:

0	0	0	0	0	0
0	1	2	2	1	0
0	1	1	0	3	0
0	2	4	1	5	0
0	2	1	2	0	0
0	0	0	0	0	0

Find the maximum from the window. Here it is 4. Similarly, find the maximum by sliding the window on the whole matrix. Thus output matrix becomes:

2	2	3	3
4	4	5	5
4	4	5	5
4	4	5	5

Consider the elements in the window 3x3

0	0	0	0	0	0
0	1	2	2	1	0
0	1	1	0	3	0
0	2	4	1	5	0
0	2	1	2	0	0
0	0	0	0	0	0

i.e.

1	2	2
1	1	0
2	4	1

Similarly the following steps can be used to implement *min* filter:

1. Find the darkest points in an image.
2. Also find the minimum value in the area encompassed by the filter.
3. Reduces the salt noise as a result of the min operation.
4. The 0th percentile filter is *min* filter.

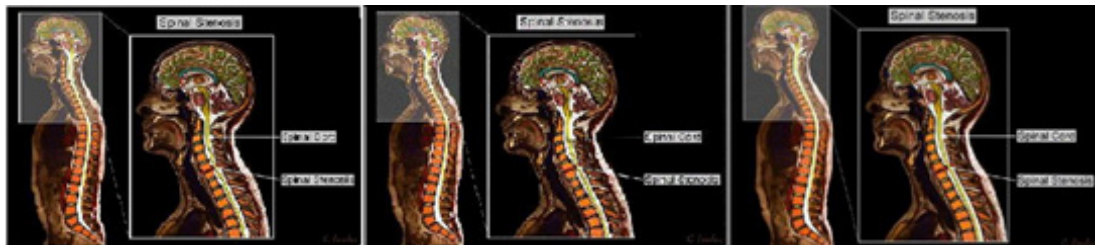


Fig. 24. (i) Input Image (ii) Poisson crashed Image (iii) Image clarified with Gaussian 5x5 filter masks

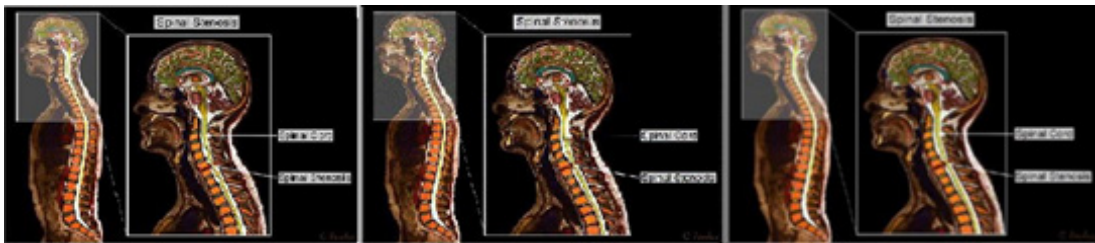


Fig. 25. (i) Input Image (ii) Poisson crashed Image (iii) Image clarified with Average 5x5 filter masks

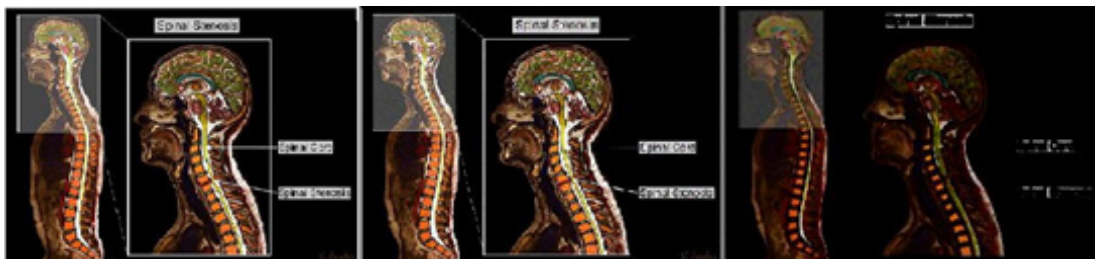


Fig. 26. (i) Input Image (ii) Poisson crashed Image (iii) Image clarified with MIN 5x5 filter masks

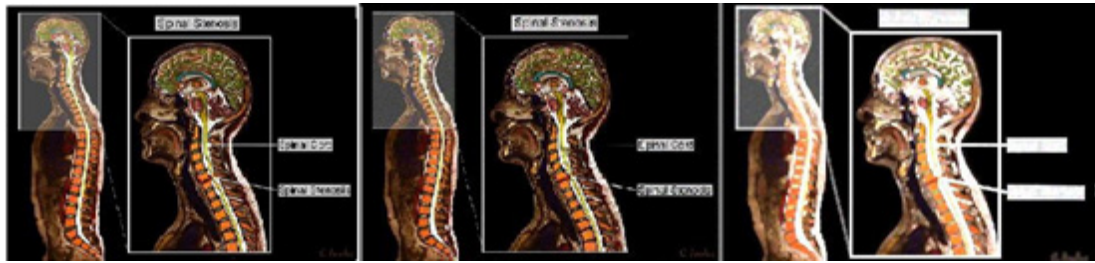


Fig. 27. (i) Input Image (ii) Poisson crashed Image (iii) Image clarified with MAX 5x5 filter masks



Fig. 28. (i) Input Image (ii) Poisson crashed Image (iii) Image clarified with Wiener 5x5 filter masks

RESULTS AND DISCUSSION

Image restoration techniques as discussed in section 3 has been applied to degraded 3D cervical spine MRI image to improve de noising of the image. In the figures 5- 10, input image is corrupted using Salt & Pepper Noise and restoration of the image using various restoration techniques to preserve the shape transitions has been shown.

Restoring Salt & Peppernoiseusing 5X5 Windows Filters

Restoring Gaussian Noiseimageusing 5X5 Windows Filters

The figures 11-16 depicts restoration of input image crashed using Gaussian Noise using several 5x5 filter masks to improve clarity of image.

Restoring Speckle Noise Image using 5X5 Windows Filters

In the figures 17-22 restoration of input image degraded with the addition of speckle Noise using several 5x5 window filters to recover the original image have been presented.

Restoringpoisson Noiseimageusing 5X5 Windows Filters

The restoration of image corrupted using poisson noise using various restoration techniques has been achieved in the figures 23-28.

Filter performance Analysis MSE (Mean Square Error)

It has been observed that for salt & pepper noise image of the cervical spine MRI as shown in figures 5-10, the MSE values of Gaussian filter window 5x5 is much better than other filters as can be seen in table 1. It can also be observed that wiener filter has provided better performance for degraded 3D cervical spine MRI image using Gaussian, speckle and Poisson noise as presented in table 1.

PSNR(Peak Signal to Noise Ratio)

In table 2, it has been shown that for corrupted 3D cervical spine MRI images with the addition of salt and pepper, Gaussian, Speckle and Poisson, the wiener filter 5x5 window has provided a better peak signal to noise ratio. It can also be analyzed that performance of Gaussian filter with 5x5 window is also good or stable for considered corrupted images.

CC(Cross Correlation)

For 3D cervical spine MRI image degraded with Salt & Pepper noise, cross correlation values of Gaussian filter are much better than other filters used to recover the original image as shown in table 3. But cross correlation values of wiener filter 5x5 window is much better than other filters

which are used in the proposed work for Gaussian, speckle and Poisson noise image as can be seen in table3.

CONCLUSION

Image restoration techniques for medical images are not so much developed in the present scenario, but their use for proper application and performance measure is still a matter of ongoing research. In the proposed work, different linear and nonlinear restoration techniques have been applied to noisy images which are corrupted with the addition of Salt and Pepper, Gaussian, Speckle and Poisson noises to recover the image. The quantitative analysis using numerical parameters

like MSE, PSNR and CC of linear and nonlinear filters for noisy images has been carried out in this proposed research work. It can be concluded that the Wiener Filter with 5x5 window is the best filter for Gaussian, speckle and Poisson noise, according to the experimental results on 3D cervical spine MRI Image. Also, Gaussian filter with 5x5 window is the best filter in order to de noise and restores 3D cervical spine MRI image degraded by the addition of salt & pepper noise. The restoration techniques used in the proposed work can be used to retain the structural details of the medical image.

Conflict of Interest

Authors of the proposed research work declare that he/she has no conflict of interest.

Table 1. Mean SquareErrorfor5x5window filters for RGB image

Name of Filter	Type of Noise			
	Salt and Pepper	Gaussian	Speckle	Poisson
Median	960.671	931.219	996.432	947.076
Gaussian	561.046	483.578	414.973	358.538
Average	1089.27	1088.03	1032.48	997.02
Min	5626.37	4518.35	4175.24	3929.38
Max	25225.5	7666.69	6060.06	5360.14
Wiener	556.294	303.88	245.605	161.058

Table 2. Peak Signal to Noise Ratio for 5x5 window filters for RGB image

Name of Filter	Type of Noise			
	Salt and Pepper	Gaussian	Speckle	Poisson
Median	18.3051	18.4403	18.1463	18.367
Gaussian	20.6408	21.2861	21.9506	22.5855
Average	17.7595	17.7644	17.992	18.1438
Min	10.6285	11.581	11.924	12.1876
Max	4.1124	9.2847	10.306	10.839
Wiener	20.6778	23.3038	24.2284	26.061

Table 3. Cross Correlation for 5x5 window filters for RGB image

Name of Filter	Type of Noise			
	Salt and Pepper	Gaussian	Speckle	Poisson
Median	0.637	0.61922	0.633	0.637
Gaussian	0.6261	0.61609	0.6592	0.6637
Average	0.5763	0.56211	0.6049	0.6083
Min	0.3715	0.51327	0.5213	0.5164
Max	0.1733	0.37174	0.4931	0.4963
Wiener	0.6309	0.63391	0.6764	0.6828

REFERENCES

1. James and B.Dasarathy Medical image fusion: A survey of the state of the art, *Information Fusion*, **19**: 4-19 (2014).
2. S. Suhas and C.R. Venugopal, "MRI Image Processing and Noise Removal Technique using Linear and Nonlinear filters", IEEE International Conference on Electrical, Electronics, Communication, Computer and Optimization Techniques (ICECCOT); **9**:709-712 (2017).
3. M. R. Banham and A. K. Katsaggelos, Digital image restoration IEEE Signal Processing Magazine, **14**: 24-41 (1997).
4. Anmol Sharma and Jagroop Singh Image Denoising using Spatial Domain Filters: A Quantitative Study 6th IEEE International Congress on Image and Signal Processing, **7**:293-298 (2013).
5. Nguyen ThanhBinh and Ashish Khare Adaptive complex wavelet technique for medical image denoising proceedings of the third International Conference on the development of Biomedical Engineering, Vietnam, 195-198 (2015).
6. S.Kaur Noise Types and Various Removal Techniques International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE); **4**:226-230 (2015).
7. B.Shinde, D. Mhaske, M.Patare, A.R. Dani Apply Different Filtering Techniques To Remove The Speckle Noise Using Medical Images *International Journal of Engineering Research and Applications*, **2**:1071-1079 (2012).
8. A. Aboshosha, et al Image denoising based on spatial filters, an analytical study International Conference on Computer Engineering & Systems; 245-250 (.).
9. CharuKhare and Kapil Kumar Nagwanshi Image Restoration Technique with Non-Linear Filter *International Journal of Advanced Science and Technology*, **39**: 67-44 (2012).
10. A. Mahmoud, S. EL Rabaie, T. E. Taha, O. Zahran, F. E. Abd El-Samie Comparative study between different denoising filters for speckle noise reduction in ultrasonic B-mode images 8th International Computer Engineering Conference (ICENCO), 30-36 (2012).
11. Oge Marques Practical Image and Video Processing Using MATLAB Wiley, New York, (2011).
12. H.M. Ali MRI Medical Image De noising by Fundamentals filters High-Resolution Neuro imaging - Basic Physical Principles and Clinical Applications, 111-124 (2018).