



Evaluation of the Performances of Homomorphic and Non-homomorphic Speckle Noise Filtering Techniques

Martin C. Eze¹, Charles C. Osuagwu²
Department of Electronic Engineering,
University of Nigeria, Nsukka, NIGERIA.

Abstract: Homomorphic and non-homomorphic filtering have been used in speckle noise removal from images but the homomorphic technique is more widely used. In this paper, the performance of the homomorphic and non-homomorphic averaging filter, wiener filter and median filter were investigated. From the result of the simulations, the homomorphic median filtering gave higher average Peak Signal to Noise Ratio (PSNR) of 71.505dB compared to 70.2675dB for non-homomorphic median filtering. On the other hand, the non-homomorphic wiener filtering gave higher average Peak Signal to Noise Ratio (PSNR) of 69.0366dB compared to 64.4828dB for homomorphic wiener filtering. Considering averaging filtering, the non-homomorphic averaging filtering gave higher average Peak Signal to Noise Ratio (PSNR) of 67.8007dB compared to 64.1402dB for homomorphic averaging filtering. Ten (10) samples of 85x73 Computerized Tomography (CT) images corrupted by speckle noise were used in the simulations for noise level ranging from 10% to 30%. The simulation software used in the paper is Matrix Laboratory (MATLAB).

Keywords: CT Images, Homomorphic filtering, Non-homomorphic filtering, Peak Signal to Noise Ratio, Speckle noise

I. Introduction

Images become corrupted by noise during acquisition and transmission [1], [2]. Many image filtering techniques are available in the literature for reducing various noise types such as Gaussian noise, Speckle noise and impulse noise [3]. The median filter is good in the removal of both impulse and speckle noise [4]. For speckle noise [4] and Gaussian noise removal [3], the wiener filter performs well while averaging filter performs well for Gaussian noise removal.

In the literature, both homomorphic and non-homomorphic technique have been used for speckle noise filtering. In [5], [6], [7], [8], [9] homomorphic filtering was used in removing speckle noise from images. The researchers in [6], [8], [9] used homomorphic wiener filtering while the researcher in [5] used homomorphic median filtering. In work done by [10], non-homomorphic Laplacian filtering was used while in the work done by [11],[9] non-homomorphic median filtering were used.

In this paper, the homomorphic and non-homomorphic filtering techniques for speckle noise removal are investigated using wiener filter, median filter and averaging filter and their performances.

II. Methodology

In this paper, the performances of the three filters are investigated in homomorphic and non-homomorphic mode. The filters investigated are wiener filter, median filter and averaging filter. In general, noiseless image, $Y(m,n)$ corrupted by a multiplicative noise, $N(m,n)$ is given as shown in (1) where $X(m,n)$ is the noisy image [7].

$$X(m,n) = Y(m,n)N(m,n) \quad (1)$$

Equation (1) is filtered using homomorphic filtering as in [5] - [8] or non-homomorphic filtering as in [10].

A. Homomorphic filtering

Homomorphic filtering involves transforming multiplicative noise into additive noise and then applying a filtering operation [12]. When the multiplicative noise is speckle noise, it is transformed to additive noise using a logarithmic transformation [6] and then filtering operation is applied [13]. Before the application of logarithmic transformation to (1), the parameter, $X(m,n)$ is corrected for the presence of zero values. Adding the correcting factor (β) to both sides of (1) gives (2) where the parameter, β in (2) is a real number such that $\beta \leq 10^{-7}$.

$$X(m,n) + \beta = Y(m,n)N(m,n) + \beta \quad (2)$$

Transforming (2) into image corrupted by additive noise using logarithmic transformation according to [7], yields (3).

$$\log_e(X(m, n) + \beta) = \log_e(Y(m, n)N(m, n) + \beta) \quad (3)$$

The correcting factor (β) is added to equation (1) before logarithmic transformation because the pixels with zero values give $-\infty$ after logarithm transformation and therefore, zero pixels need modification to ensure real value after transformation. The value of β is made very negligible to avoid excessive change in pixel values. The use of averaging filter to remove speckle noise from image after logarithmic transformation is known as homomorphic averaging filtering. The expression for homomorphic averaging filtering is given in (4) where $\bar{Y}(m, n)$ is the filtered image.

$$\bar{Y}(m, n) = \text{Exp}\left(\frac{1}{M_f N_f} \sum_{j=-R_f}^{R_f} \sum_{k=-C_f}^{C_f} \log_e(X(m, n) + \beta)\right) \quad (4)$$

The parameters M_f and N_f are the row and column sizes of the filter respectively.

The use of wiener filter to remove speckle noise from image after logarithmic transformation, the operation is known as homomorphic wiener filtering. The expression for homomorphic wiener filtering is given in (5).

$$\bar{Y}(m, n) = \text{Exp}\left(\text{wiener}(\log_e(X(m, n) + \beta))\right) \quad (5)$$

On the other hand, the use of median filter to remove speckle noise from image after logarithmic transformation, the operation is known as homomorphic median filtering. The expression for homomorphic median filtering is given in (6).

$$\bar{Y}(m, n) = \text{Exp}\left(\text{median}(\log_e(X(m, n) + \beta))\right) \quad (6)$$

B. Non-homomorphic filtering

Non-homomorphic filtering involves applying a filtering operation to image corrupted by speckle noise without initial logarithmic transformation. The use of averaging filter to remove speckle noise from image without logarithmic transformation, the operation is known as non-homomorphic averaging filtering. The expression for non-homomorphic averaging filtering is given in (7).

$$\bar{Y}(m, n) = \frac{1}{M_f N_f} \sum_{j=-R_f}^{R_f} \sum_{k=-C_f}^{C_f} X(m, n) \quad (7)$$

When wiener filter is used to remove speckle noise from image without initial logarithmic transformation, the operation is known as non-homomorphic wiener filtering. The expression for non-homomorphic wiener filtering is given in (8).

$$\bar{Y}(m, n) = \text{wiener}(X(m, n)) \quad (8)$$

The use of median filter to remove speckle noise from image without logarithmic transformation, the operation is known as non-homomorphic median filtering. The expression for non-homomorphic median filtering is given in (9).

$$\bar{Y}(m, n) = \text{median}(X(m, n)) \quad (9)$$

The use of non-homomorphic filtering makes the operation faster and the algorithm simpler.

III. Performance metrics

The effectiveness of homomorphic and non-homomorphic techniques is estimated using Peak Signal-to-Noise Ratio (**PSNR**). The **PSNR** of a noisy image is the ratio of the maximum power of the signal to the maximum power of the noise distorting the image [14]. For a normalized image, the PSNR is written as shown in (10). The 63dB is added to ensure that all values are positive.

$$\text{PSNR} = 63\text{dB} + 10\log_{10}\left(\frac{1}{\text{MSE}}\right) \quad (10)$$

$$\text{Where } \text{MSE} = \frac{1}{MN} \sum_{m=1}^M \sum_{n=1}^N [Y(m, n) - \bar{Y}(m, n)]^2 \quad (11)$$

MSE given (11) is the mean square error. The PSNR is measured in decibel.

IV. Result and discussion

The performances of homomorphic and non-homomorphic techniques in effectively removing speckle noise from noisy images were investigated using ten (10) samples of 85x73 CT lung images corrupted by speckle noise of variance ranging from 10% to 30%. The PSNR values calculated in this paper using (10) for homomorphic and non-homomorphic median, wiener and averaging filters are shown in tables 1, 2 and 3 respectively.

Table 1: The PSNR values for homomorphic and non-homomorphic median filtering

Filter \ Noise Variance (%)	10	15	20	25	30	Average PSNR(dB)
	PSNR(dB)					
3X3 Homomorphic median filtering	73.4217	72.2690	71.2482	70.7978	69.7881	71.505
3X3 Non-homomorphic median filtering	72.6325	71.1584	69.9108	69.2741	68.3616	70.2675

Table 1 shows how the PSNR values for homomorphic and non-homomorphic median filtering vary with the speckle noise variance present in the noisy images. From table 1, it is observed that homomorphic median filtering gave higher average PSNR (**71.505dB**) compared to Non-homomorphic median filtering (**70.2675dB**). The trend in table 1 is clearly shown in fig. 1. From fig. 1, it is observed that for all noise levels considered, the homomorphic median filtering gave higher values of PSNR. This shows that the homomorphic median filtering gives better performance.

Fig.1: Plot of PSNR against noise variance for Homomorphic and Non-homomorphic median filtering

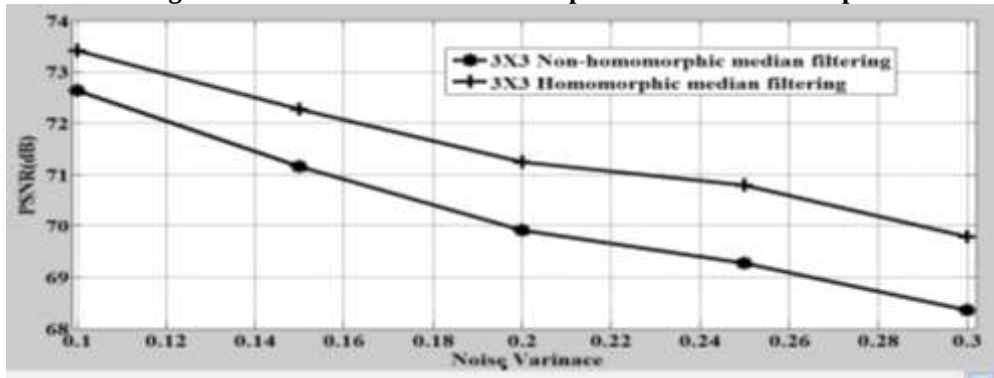


Table 2: The PSNR values for homomorphic and non-homomorphic wiener filtering

Filter \ Noise Variance (%)	10	15	20	25	30	Average PSNR(dB)
	PSNR(dB)					
3X3 Homomorphic Wiener filtering	68.7854	66.2169	64.1270	62.4348	60.8499	64.4828
3X3Non-homomorphic Wiener filtering	72.5602	70.2997	68.6975	67.3503	66.2751	69.0366

Considering table 2, it is also observed that the non-homomorphic wiener filtering gave a larger value of PSNR (**69.0366dB**) compared to homomorphic wiener filtering (**64.4828dB**). The trend in table 2 is clearly shown in fig.2. From fig. 2, it is observed that for all noise levels considered, the non-homomorphic wiener filtering gave larger values of average PSNR and therefore has better performance.

Fig. 2: Plot of PSNR against noise variance for Homomorphic and Non-homomorphic wiener filtering

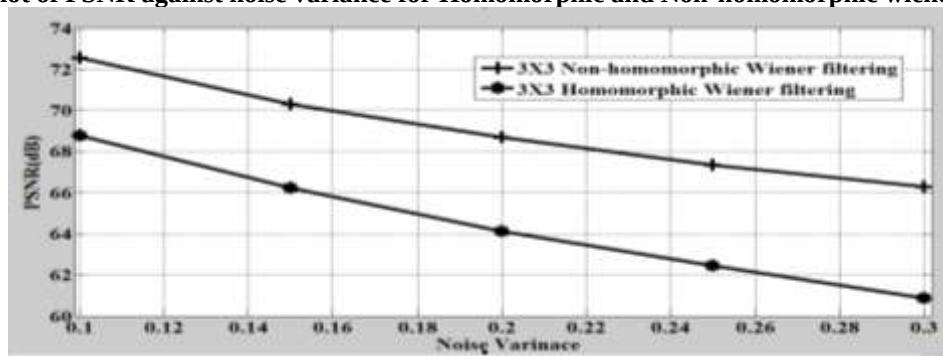
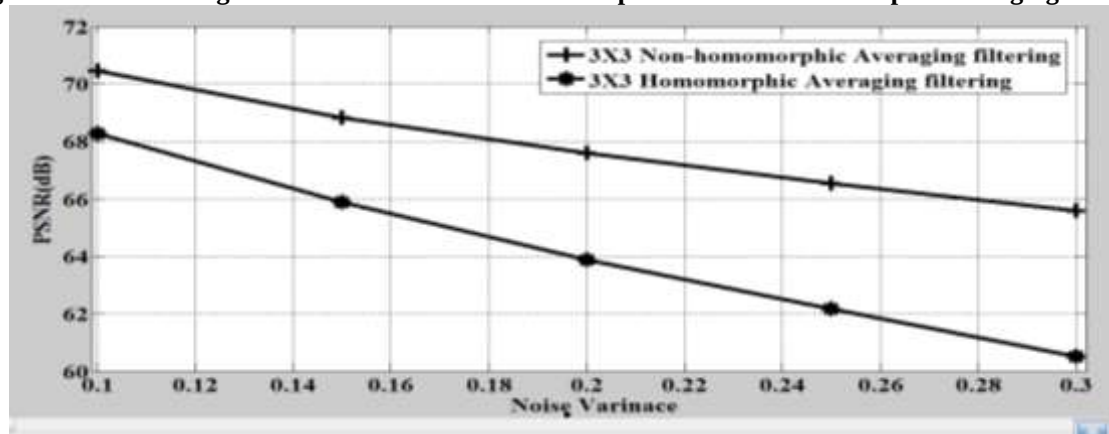


Table 3: The PSNR values for homomorphic and non-homomorphic averaging filtering

Filter \ Noise Variance	0.10	0.15	0.20	0.25	0.30	Average PSNR(dB)
	PSNR(dB)					
3X3 Homomorphic Averaging filtering	68.2612	65.8771	63.8763	62.1841	60.5023	64.1402
3X3 Non-homomorphic Averaging filtering	70.4491	68.8285	67.5954	66.5379	65.5927	67.8007

Considering table 3, it is also observed that the non-homomorphic averaging filtering gave a larger value of PSNR (**67.8007dB**) compared to homomorphic averaging filtering (**64.1402dB**). The trend in table 3 is clearly shown in fig.3. From fig. 3, it is observed that for all noise levels considered, the non-homomorphic averaging filtering gave larger values of average PSNR and therefore has better performance.

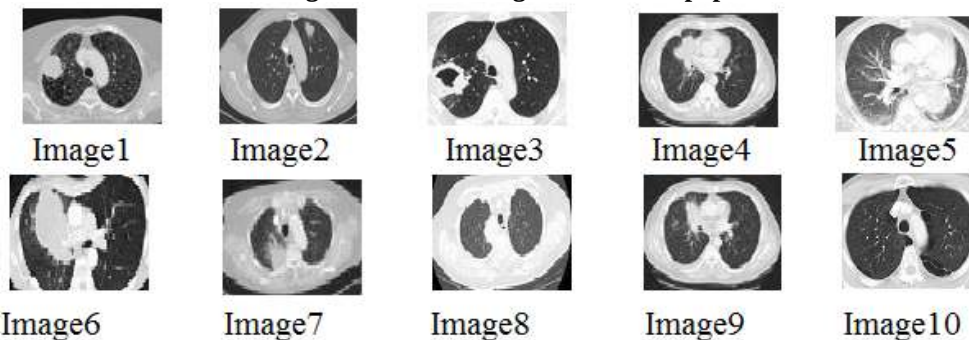
Fig. 3: Plot of PSNR against noise variance for Homomorphic and Non-homomorphic averaging filtering



V. CT lung Images used in the paper

The CT images used in the paper are shown in fig.4. The images are of sizes 85X73. Figure 5 shows the images with each corrupted by 30% speckle noise.

Fig. 4: Noiseless images used in the paper



Source: <http://radiopaedia.org>

Fig. 5: Unfiltered images corrupted by 30% noise

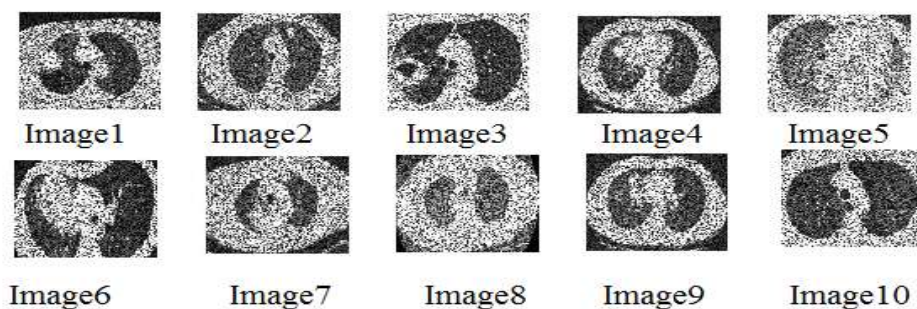


Fig. 6: 30% noisy Images filtered using homomorphic Wiener Filtering

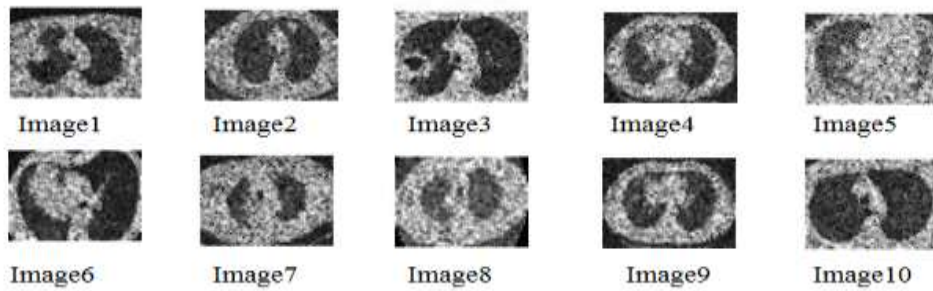


Fig. 7: 30% noisy Images filtered using non-homomorphic Wiener Filtering

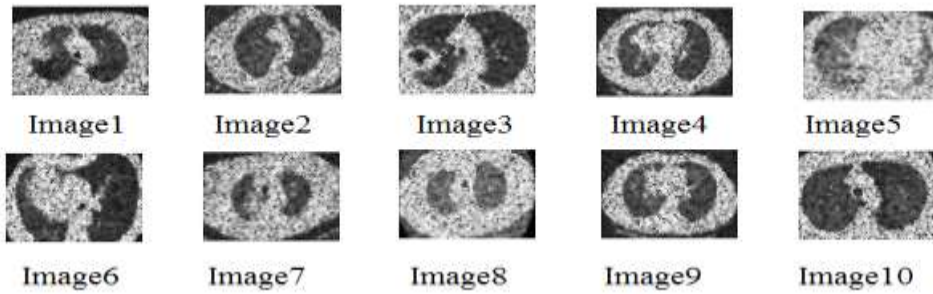


Fig. 8: 30% noisy Images filtered using homomorphic median Filtering

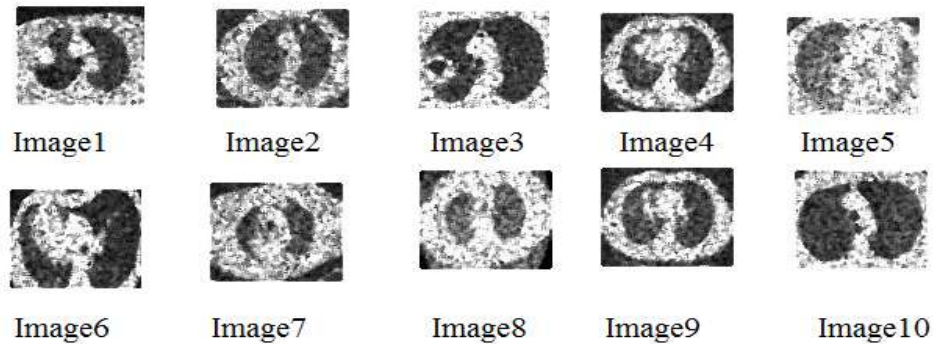


Fig. 9: 30% noisy Images filtered using non-homomorphic median Filtering

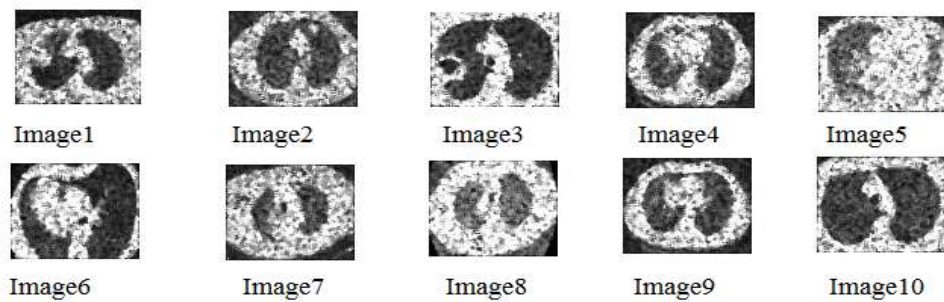


Fig. 10: 30% noisy Images filtered using homomorphic averaging filtering

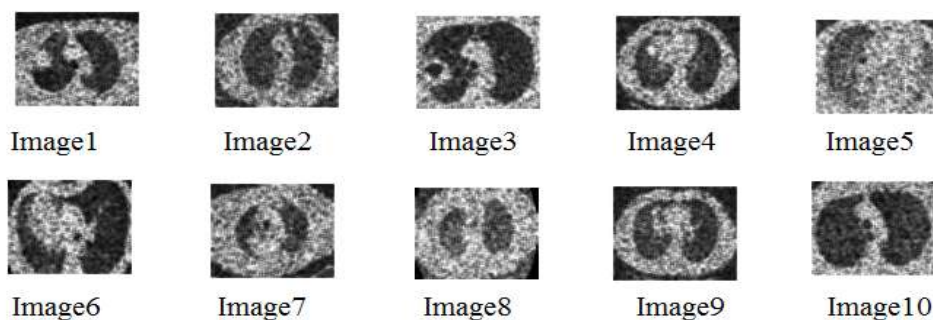
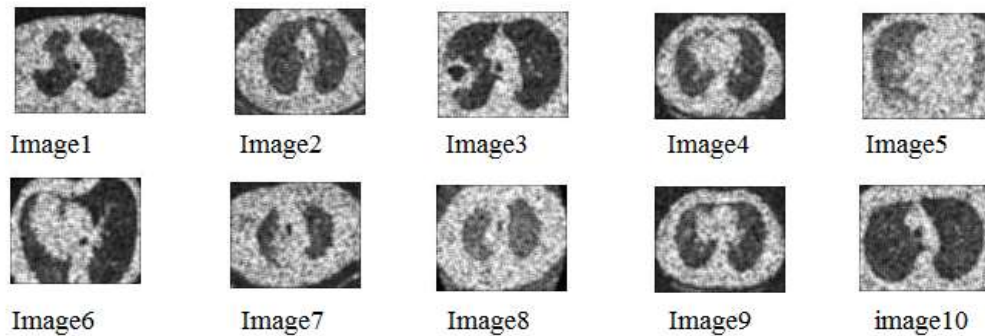


Fig. 11: 30% noisy Images filtered using non-homomorphic averaging filtering



Figures 6, 8 and 10 show the noisy images in fig.5 filtered using homomorphic wiener filtering, median filtering and averaging filtering respectively. On the other hand, figures 7, 9 and 11 show the noisy images in fig.5 filtered using non-homomorphic wiener filtering, median filtering and averaging filtering respectively. Based on visual observation, it is seen that images filtered using homomorphic median filtering have better visual details compared to images filtered using non-homomorphic median filtering. In case of wiener filter and averaging filter, the images filtered using non-homomorphic filtering has better visual details.

VI. Conclusion

In this paper, the performances of homomorphic and non-homomorphic filtering techniques for speckle noise filtering were successfully investigated. Based on the observation, it is noticed that some filters perform better in homomorphic filtering while others perform better in the non-homomorphic filtering. From the simulation, median filter performs better in homomorphic filtering while wiener and averaging filter performs better in non-homomorphic filtering for noise variance ranging from 10% to 30%.

VII. References

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VIII. Acknowledgments

We thank immensely Conquest Medical Imaging, Trans Ekulu, Enugu for their invaluable technical contribution during this research.