International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.9, No.12, (2016), pp.11-18
http://dx.doi.org/10.14257/ijsip.2016.9.12.02

Preserving the Edges of a Digital Image Using Various Filtering Algorithms and Tools

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Abstract

Digital Image Processing is basically the implementation of a set of computer algorithms for processing digital images. Digital image processing has probative advantages over Analog image processing. In this content, noise like, Gaussian, Salt and Pepper, Speckle and Poisson, is added to an image and then the original edges are restored using various filters and tools. These tools have remarkable alteration on the image and hence they are widely employed. Some of them are wavelet transform, median filter, Weiner filter and many more.

Keywords: *Digital Image, Algorithms, Gaussian noise, Salt and Pepper noise, Speckle noise, Poisson noise, Median filter, Weiner filter*

1. Introduction

De-noising of an image is a crucial task in digital image processing. There are various methods exist to de-noise an image. The significances of a good image de-noising filter is determined by the extent to which it removes noise from the image to get the replica of the original one. Traditionally, there are two types of de-noising models Linear de-noising model and Non-liner de-noising model [11]. The advantages of linear de-noising models is the processing speed but using this model, edges of the original image cannot be preserved efficiently. But due to its good processing speed and the ease of handling, this model is generally used. On the second side of coin, Edges of an image can be preserved in a much better way in the case of non-linear de-noising models than linear models. Total Variation (TV)-filter is one the best methods of non-linear de-noising models [2].

2. Types of Image Noise

Image noise is the random and irregular variations of color information in images. Image noise can be found in the form of grain and unavoidable shot noise of an ideal photon detector. These undesirable disorder of image components which can be treated to preserve edges of image is known as noise. There are various types of Noise. Some of them are following:-1.Gaussian noise), 2.Salt-and-pepper noise, 3. Speckle noise, 4. Poisson noise.

ISSN: 2005-4254 IJSIP

2.1. Gaussian Noise

The basic features of Gaussian noise is additive, independent at each pixel and independent of the signal intensity [12]. More amplification in blue color channel is used in color cameras than in the green or red channel because in the blue channel, there exist more noise as compare to the rest of two channels [4]. This noise is also known as 'Amplifier Noise'. The probability density function p of a Gaussian random variable z is given by:

$$p_G(z) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(z-\mu)^2}{2\sigma^2}} \tag{1}$$

Where z represents grey level, μ the mean value and σ the standard deviation [7].

2.2. Salt and Pepper Noise

An image having salt-and-pepper noise has black points (pixels) in bright regions and white points(pixels) in dark regions [4]. The region behind this noise can be the dead pixels, errors generated during Analog to Digital conversion, bit errors during transmission, *etc.*, the only way to eliminate the dark and bright pixels is to use dark frame subtraction and interpolating around dark/bright pixels. Generally, such noise containing image is preserved using Median Filter [8].

2.3. Speckle Noise

Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar (SAR) images. It increases the mean grey level of a local area. Speckle noise in SAR is generally more hectic and that cause difficulties for image restoration [5]. It is caused by coherent processing of scattered signals from multiple distributed targets. Speckle noise is caused by signals coming from elementary scatters and the gravity-capillary ripples. Speckle noise in SAR is a multiplicative noise, *i.e.*, it is in direct proportion to the local grey level in any area [9]. Generalized model of the speckle [3] is represented as,

$$g(n, m) = f(n, m) * u(n, m) + \xi(n, m) \tag{2}$$

Where g (n, m), is the observed image, u (n, m) is the multiplicative component, ξ (n, m) is the additive component of the speckle noise. Here n and m denotes the axial and lateral indices of the image samples [10].

2.4. Poisson Noise

Poisson noise is also known as shot noise. It is a type of electronic noise. It occurs when the finite number of particles that carry energy, for example, electrons in an electronic circuit or photons in an optical device, is small enough which causes fluctuations in a measurement [4].

3. Types of Filters

De-noising process needs a complex set of algorithms which detect the actual edges of an image to get the image similar to the original one. This sets of algorithms are knows as de-noising filters. The different types of filters are average filter, median filter, weiner filter and many more [13].

In many cases, a given signal might be analyzed using various transformations to alter the signal domain. There are several transforms available like the Fourier transform, Hilbert transform, wavelet transform, *etc.* Probably the most popular transform is Fourier transform [3].

3.1. Average Filter

For reducing grain noise from an image, an Average filter is used. This filter fits the pixels of the image on the basis of their adjacent pixels. In this way, local variations caused by grain are reduced using Average filter. The Average Filter is a linear filter which creates a mask above each pixel of the image. Each components of the pixels that comes under the mask are averaged together to form a single pixel [6]. This filter is also called as Mean filter. Due to the simple algorithms used in Average filter, edges are not completely preserved. The Average filter is defined by:

$$\text{Mean filter } (x_1 \ldots x_N) = 1/N \sum_{i=1}^{N} x_i \quad (3)$$

where $(x_1 \ldots x_N)$ is the image pixel range.

3.2. Median Filter

Median filter is a type of non-linear filtering model. Median filter is most widely used in digital image processing because under specific circumstances, it recovers edges and removes noise efficiently. The principle of the median filter is to visit each pixel and to replace each pixel with the median of its adjacent pixels. Note that if there is a odd number of pixels count, then the middle value is the median but for the even count of the pixels there would more than one possible medians. Median filters are widely used for smoothening of image in digital image processing as well as in signal processing [6]. The great advantages of the median filter is that it can preserve the edges of image under processing with extremely large magnitudes. The output(y) of the median filter at the moment(t) is calculated as the median of the input values corresponding to the moments adjacent to t:

$$y(t) = \text{median}((x(t-T/2), x(t-T1+1), \ldots, x(t), \ldots, x(t+T/2)) \quad (4)$$

Where ‘t’ is the size of the window of the median filter.

Besides the one-dimensional median filter described above, there are two-dimensional median filters used in image processing. In two-dimensional image, each element of image is defined by pixel having two indices- row and column.

3.3. Weiner Filter

The main aim Weiner filter is filter out the noise which has corrupted the image signal. The Weiner is based on the statistical approach. The filtering approach of Weiner filter is to filter all the noise signal present in the image from different angles [1]. The Weiner filter is defined as-

$$G(u, v) = H^*(u, v)\, P_s(u, v) / [\, |H(u, v)|^2 P_s(u, v) + P_n(u, v)] \quad (5)$$

Where
$H(u, v)$ = Degradation function
$H^*(u, v)$ = Complex conjugate of degradation function
$P_n(u, v)$ = Power Spectral Density of Noise
$P_s(u, v)$ = Power Spectral Density of un-degraded image

4. Simulation Results

Here is the original image of blood cell which is get mixed with the four noises- Gaussian, Salt and Pepper, Speckle and Poisson. After that, each of four noisy images is allowed to process with different filters- Average, Median and Weiner.

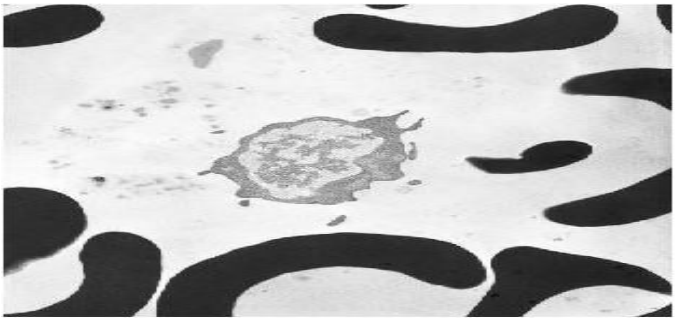
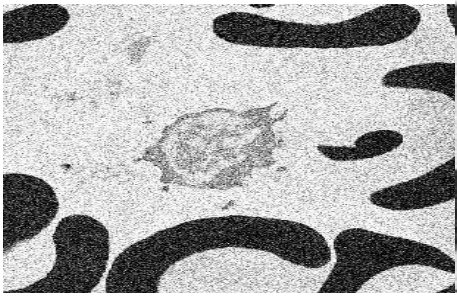


Figure 1. Blood Cell

4.1. De-Noising of Gaussian Noise



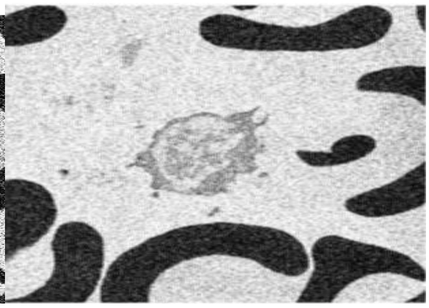
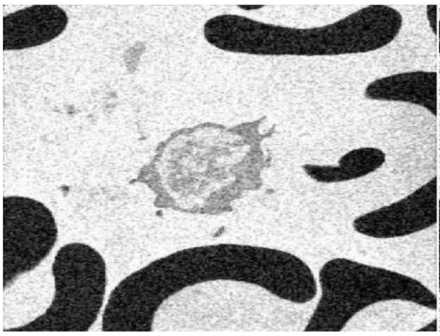


Figure 2. Noisy Image (Gaussian) **Figure 3. Using Average Filter**



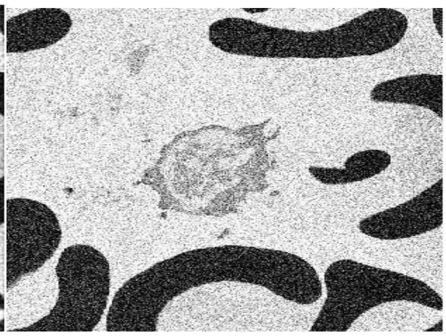
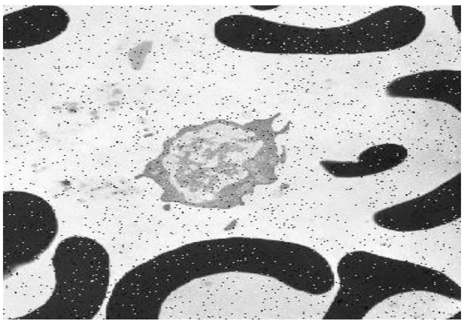


Figure 4. Using Median Filter **Figure 5. Using Weiner Filter**

4.2. De-Noising of Salt and Pepper Noise



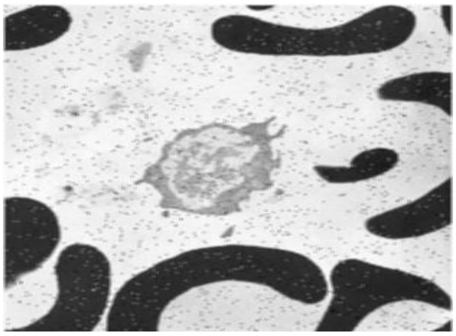


Figure 6. Noisy Image (Salt & Pepper) **Figure 7. Using Average Filter**

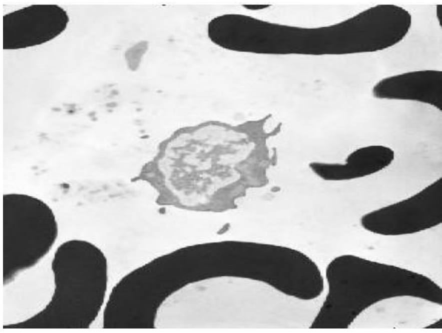


Figure 8. Using Median Filter

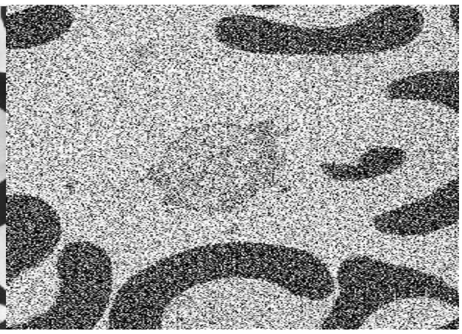


Figure 9. Using Weiner Filter

4.3. De-Noising of Speckle Noise

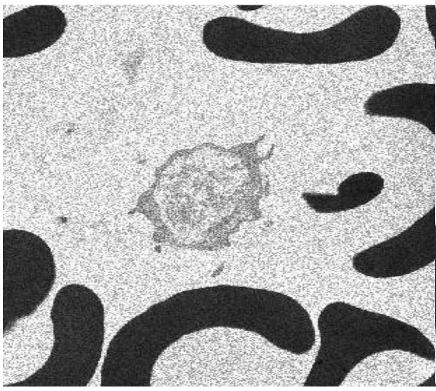


Figure 10. Noisy Image (Speckle)

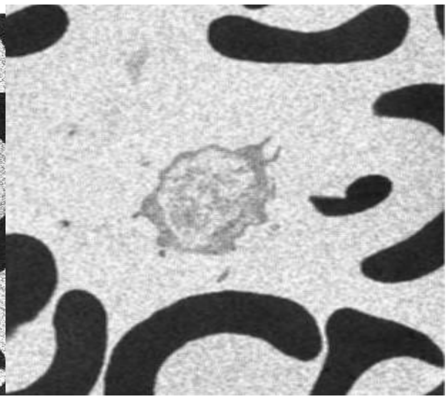


Figure 11. Using Average Filter

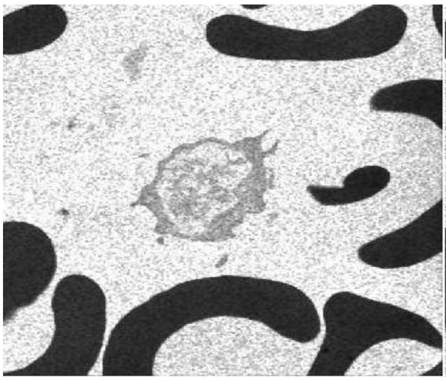


Figure 12. Using Median Filter

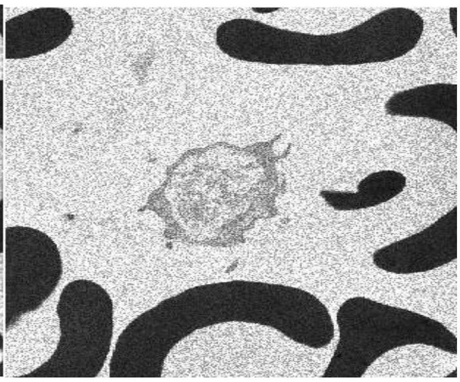


Figure 13. Using Weiner Filter

4.4. De-Noising of Poisson Noise

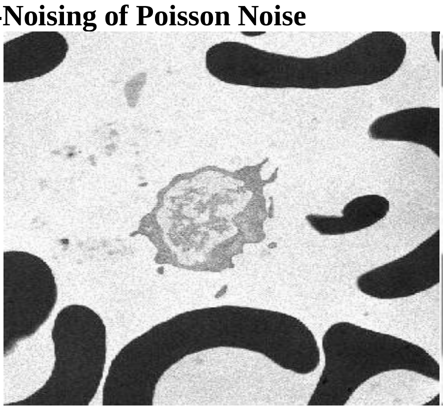


Figure 14. Noisy Image (Poisson)

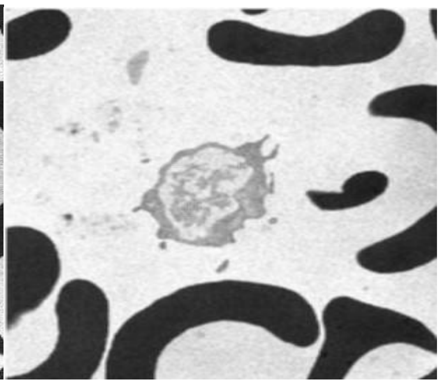


Figure 15. Using Average Filter

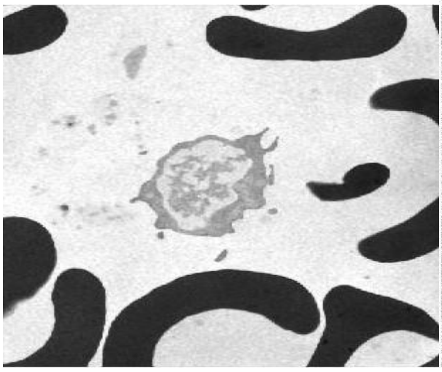


Figure 16. Using Median Filter

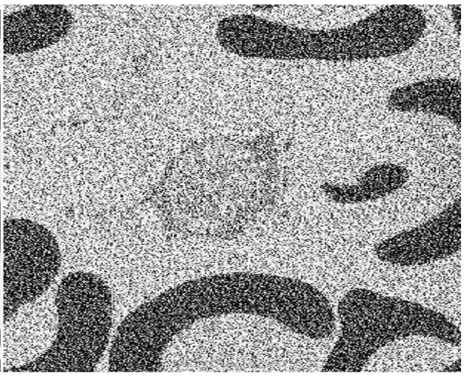


Figure 17. Using Weiner Filter

5. Conclusion

In above simulation, four different noises (Gaussian, Salt & Pepper, Speckle and Poisson) are added in the original image of blood cell with standard deviation (0.025). After that all the four noisy images are allowed to preserve their edges using different filters (Average, Median and Weiner).

Conclusion derived from above simulation are-

- Since the Wiener Filter preserves edges from different angles, hence, it can be used for restoring blurred image.
- The performance of the Average filter is better in the case of Poisson Noise.
- The performance of the Median filter is quite good in each case but for the Salt and Pepper Noise, it is the best option.
- In spite of the complexity of the non-linear de-noising model, this model is better de-noising algorithms in comparison with linear de-noising model.

6. Scope in Future Work

There are a couple of areas in which improvement can be made using image de-noising. Another area of improvement would be to develop a better optimality criterion as the MSE is not always the best optimality criterion. The future work of research would be to implement Wiener Filter in Wavelet Domain, applying the methods in which the noise variance is known & in which the noise variance is unknown *i.e.*, the MAD method.

These De-noising tools can be employed in processing the visual image of the road-side indication which can be quit helpful in safe driving.

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