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PERFORMANCE ANALYSIS OF VARIOUS LYMPHOCYTES IMAGES DE-NOISING FILTERS OVER A MICROSCOPIC BLOOD SMEAR IMAGE

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ABSTRACT

Image Enhancement is the first and foremost step that has to be done in all image processing applications. It is used to improve the quality of digital images. Microscopic images are prone to addition of noise from various sources such as error in camera calibration, excess staining of microscopic slides, etc.; Image de-noising is an enhancement technique that is used to remove noise present in an image. Reducing noise of image and preserve the edges are always critical and challenging in image processing. In this paper we made an attempt to undertake the study of four types of noise (Salt-and-pepper, Gaussian noise, Speckle Noise and Poisson Noise) induced in a peripheral blood smear image and their removal using four types of spatial filters (Mean Filter, Median Filter, Gaussian filter and Wiener Filter), in order to judge the efficiency of various filters over different kind of noise. For estimation of parametric values we can use Mean Square Error (MSE), Normalized Absolute Error (NAE) and Normalized correlation (NK), Peak Signal to Noise Ratio (PSNR) and it has been shown that Weiner filter is an optimum filter for microscopic images.

KEYWORDS : Microscopic Images, Noise, Errors, Denoising, Lymphocytes.

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I. INTRODUCTION

The process of life is maintained by blood, which is a specialized body fluid consisting of plasma and blood cells. To perform a proper diagnosis of the disease, identification of the blood cells and their relative quantity in the blood samples must be known. A blood film or peripheral blood smear is a thin layer of blood smeared on a microscope slide and then stained in such a way to allow the various blood cells to be examined microscopically. Due to the development in technology this traditional blood examination is digitalized. For this purpose, the blood smear slides are taken and by connecting a high resolution digital camera to microscope, images are captured by adjusting microscope magnification to get good resolution. For identifying different types of blood cells and for counting their quantity in blood smear, image processing is used on various blood smear images. The first step in image processing is image preprocessing. It is done to enhance the quality of image obtained from various sources such that it satisfies the requirement of further processing. Image De-noising is one of the preprocessing mechanisms that is used to remove noise from acquired image. Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. To understand how we can better enhance the blood smear image, this paper assess four different filtering techniques on four types of noise which can affect the blood smear images and estimates the filters performance by using four types of image quality measures. The filtering algorithms are implemented on twenty five samples for various noise types. The simulation is performed on MATLAB R2011a version. Noise removal is easier in the spatial domain as compared to the frequency domain as the spatial domain noise removal requires very less processing time[3].Thus this paper intends to perform noise removal in the spatial domain rather than use frequency Fourier transforms. The past research work emphasized on removing noise from remote sensing images[5], Binary document images[1], and underwater images[6]. The content of this paper is organized as follows: section 2 describes the types of noise which will be removed by the mentioned filters, section 3 describes the types of filters used, section 4 describes the experimental results and discussions followed by section 5 highlighting the conclusion and section 6 lists the references.

II. NOISE TYPES

Noise in any image can be grouped based on the criteria if it is dependent on the underlying content or independent of the underlying content. Stray marks, marginal noise and salt-and-pepper noise are independent of size; location of the underlying content[1].Similarly the texture of the observed speckle pattern is independent of the underlying content. Blur, pixel-shift or bleed-through on other hand is dependent noise, as they manifest themselves differently depending on the content. Such content-dependent noise is comparatively more difficult to model, mathematically nonlinear and often multiplicative. Noise can also be classified based on its consistency in properties like periodicity of occurrence, its shape, position and gray-values. If noise shows a consistent behavior in terms of these properties, it is called regular noise. On the other hand, noise such as salt-and-pepper noise that does not show a consistent behavior is classified under "irregular noise"[1]. In this paper we have made an attempt to study the four common types of noises like Gaussian, salt and pepper, Poisson and speckle noise.

A. Gaussian Noises

Gaussian noise also called Random Variation Impulsive Noise (RVIN) or normal noise T is a type of statistical noise in which the amplitude of the noise follows that of a Gaussian distribution. Gaussian Noise occurs as the probability density function of the normal distribution. Thus Gaussian Noise represents the frequency spectrum that has a bell shaped curve. Gaussian distribution noise can be expressed by:

$$p(x) = \frac{1}{(\sigma\sqrt{2\pi})} * \frac{e^{(x-\mu)^2}}{2\sigma^2} \quad (1)$$

Where:
P(x) is the Gaussian distribution noise in image;
µ and s is the mean and standard deviation respectively.

B. Salt-and-Pepper Noise

Salt-and-pepper noise is also called as Fat-tail distributed or impulsive noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. Salt and pepper noise is predominantly found in digital transmission and storage. It can be described as:

$$I(t) = (1-e)S(t) + eN(t) \quad (2)$$

Where S (t) represents the amount of dark pixels in bright regions, N (t) represents bright pixels in dark regions and I (t) represents the overall salt-and-pepper noise in the given image and e= {0, 1}, with a probability P. There is a clear 50% probability of the occurrence of either black or white pixels within the image giving rise to salt and pepper noise.

C. Poisson Noise

In image sensor statistical quantum fluctuations provoke a high-flying noise type. It is called as Poisson noise and pixels are independent each other. Obtained radiography images are always satisfying the Poisson distribution. The dark leakage current of the image sensor will produce yet another type of noise called the "dark current shot noise".

D. Speckle Noise

Speckle noise is a granular noise that increases the mean grey level of a local area in a image. This type of noise makes it difficult for image recognition and interpretation. In this noise type, the sample mean and variance of a single pixel is proportional to that of the mean and variance of the local area that is centered on that pixel. It is a deterministic, random and consists of an interference pattern.

III. IMAGE FILTERING ALGORITHMS

In image processing, filters are mainly used to suppress either the high frequencies in the image, i.e. smoothing the image, or the low frequencies, i.e. enhancing or detecting edges in the image. Image restoration and enhancement techniques are described in both the spatial domain and frequency domain, i.e. Fourier transforms. Noise removal is easier in the spatial domain as compared to the frequency domain as the spatial domain noise removal requires very less processing time[3]. Spatial processing is classified into point and mask processing. Point processing involves the transformation of individual pixels independently of other pixels in the image. These simple operations are typically used to correct the defects in image acquisition hardware, for example to compensate for under/over exposed images. On the other hand, in mask processing, the pixel with its neighborhood of pixels in a square or circle mask are involved in generating the pixel at (x, y) coordinates in the enhanced image. It is a more costly operation than simple point processing, but more powerful. The application of a mask to an input image produces an output image of the same size as the input. One of the most important requirements of noise removal algorithms is that they should provide a satisfactory amount of noise removal and also help preserve the edges. For the stated conditions to be satisfied there are two types of filters with their significant advantages and disadvantages. The two types of filters are the linear and non-linear filters. The linear filters have the advantage of faster processing but the disadvantage of not preserving edges. Conversely the non-linear filters have the advantage of preserving edges and the disadvantage of slower processing[7]. Thus this paper intends to perform noise removal in the spatial domain rather than use frequency Fourier transforms

A. Average Filter

Mean filtering is a simple, intuitive and easy to implement method of smoothing images, and to reduce the amount of intensity variation between one pixel and the next. Average filtering replaces each pixel value in an image with the mean value of its neighbors, including itself. The simplest procedure would be to calculate the mask for all the pixels in the image. For all the pixels in the image which fall under this mask, it will be considered as the new pixel[7]. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. Average filter is also considered to be a convolution filter or a mean filter.

B. Median Filter

Median filtering is one of the methods to perform this noise reduction with the help of neighborhood averaging. The neighborhood averaging can suppress isolated out-of-range noise, but the side effect is that it also blurs sudden changes such as sharp edges. The median filter is an effective method that can suppress isolated noise without blurring sharp edges. In Median Filtering, all the pixel values are first sorted into numerical order and then replaced with the middle pixel value[8]. Let y represent a pixel location and w represent a neighborhood centered around location (m, n) in the image, then the working of median filter is given by

$$y[m,n] = Median\{x[i,j], (i,j) \, belongs \, to \, w\} \qquad (3)$$

Since the pixel y[m ,n] represents the location of the pixel y ,m and n represents the x and y co-ordinates of y. W represents the neighborhood pixels surrounding the pixel position at (m, n).(i , j) belongs to the same neighborhood centered around (m, n).Thus the median method will take the median of all the pixels within the range of (i , j) represented by x[i, j].

C. Gaussian Filter

The Gaussian filter is a non-uniform low pass filter. The kernel coefficients diminish with increasing distance from the kernel's centre. Central pixels have a higher weighting than those on the periphery. Larger values of σ produce a wider peak (greater blurring). Kernel size must increase with increasing σ to maintain the Gaussian nature of the filter. Gaussian kernel coefficients depend on the value of σ. At the edge of the mask, the coefficients must be close to 0. The kernel is rotationally symmetric with no directional bias. Gaussian kernel is separable which allows fast computation. Gaussian filters might not preserve image brightness.

D. Wiener Filter

The inverse filtering is a restoration technique for de-convolution, i.e., when the image is blurred by a known low pass filter, it is possible to recover the image by inverse filtering or generalized inverse filtering. However, inverse filtering is very sensitive to additive noise. The approach of reducing degradation at a time allows us to develop a restoration algorithm for each type of degradation and simply combine them. The Wiener filtering executes an optimal trade-off between inverse filtering and noise smoothing. It removes the additive noise and inverts the blurring simultaneously. The Wiener filtering is optimal in terms of the mean square error. In other words, it minimizes the overall mean square error in the process of inverse filtering and noise smoothing. The Wiener filtering is a linear estimation of the original image. The approach is based on a stochastic framework. The orthogonality principle implies that the Wiener filter in Fourier domain can be expressed as follows:

$$w(f_1, f_2) = \frac{H * (f_1, f_2) S_{xx}(f_1 f_2)}{|H(f_1 f_2)|^2 S_{xx}(f_1 f_2) + S_{\eta\eta}(f_1 f_2)}, \qquad (4)$$

Where Sxx(f1,f2),Sηη(f1,f2) are respectively power spectra of the original image and the additive noise, and is the blurring filter. It is easy to see that the Wiener filter has two separate parts, an inverse filtering part and a noise smoothing part. It not only performs the de-convolution by inverse filtering (high pass filtering) but also removes the noise with a compression operation (low pass filtering).

IV. EXPERIMENTAL SETUP AND RESULTS

A set of 50 images had been taken for analysis. Each image is subjected to different types of noise mentioned above. Each image with added noise is subjected to different types of filters. The filtered image is compared against the original image using the following image quality measures. Results of each image quality parameter shown below

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

The Peak Signal to Noise Ratio is calculated by:

$$PSNR = 20 log_{10}\left(\frac{N}{MSE}\right) dB \qquad (5)$$

For the image quality measures, if the value of the PSNR is very high for an image of a particular noise type then is best quality image. Table I shows the aggregated PSNR value of each image subjected to different type of filters.

Table I

PSNR value for images subjected to various filters over different types of noise

Filter /Noise	Salt & Pepper Noise	Gaussian Noise	Poisson Noise	Speckle Noise
Mean Filter	26.0075	26.2839	28.1714	26.0728
Median Filter	32.6813	26.0729	29.5074	24.4857
Weiner Filter	21.2104	26.6245	30.4699	26.5855
Gaussian Filter	23.4399	24.1645	29.0728	23.8969

Figure 1 shows the graphical representation of Table I. It is seen that Median filter over salt and pepper noise have the highest PSNR value; For all other type of noise Image subjected to Weiner filter gives the highest PSNR value. Mean filter shows an average performance over all type noise then followed by Gaussian filter. According to PSNR it is clear that the Median filter gives best result over salt and pepper noise only and Wiener can remove Gaussian noise, Poisson noise and Speckle noise more effectively than all other filters.

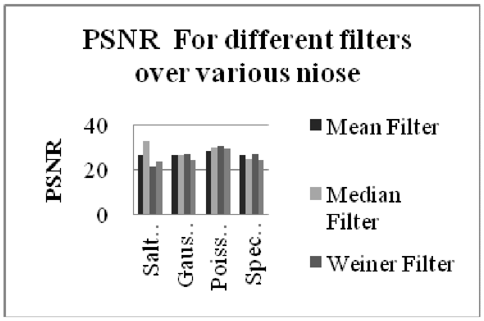

Figure 1
PSNR value for images subjected to different filters Over various types of noise

B. Mean Square Error (MSE)

Mean square error is given by

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[g(i,j) - f(i,j)]^2 \qquad (6)$$

Where M and N are the total number of pixels in the horizontal and the vertical dimensions of the image, g denotes the Noise image and f denotes the filtered image. The lowest mean square error represents the best quality image.

Table II
MSE value for images subjected to various filters over different types of noise filters over different types of noise

Filter/ Noise	Salt & Pepper Noise	Gaussian Noise	Poisson Noise	Speckle Noise
Mean Filter	163.0537	152.9985	99.0697	160.6209
Median Filter	35.0713	160.6164	72.8347	231.4779
Weiner Filter	492.0871	141.4579	58.3566	142.7363
Gaussian Filter	294.5029	249.2496	80.5016	265.0888

Figure 2 shows the graphical representation of Table II. It is seen that MSE value of an image subjected to Median filter over salt and pepper noise have the lowest value; for all other type of noise Image subjected to Weiner filter gives the lowest MSE value. Mean filter shows an average performance over all type noise then followed by Gaussian filter.

C. Normalized Correlation (NK)

The closeness between two digital images can also be quantified in terms of correlation function. These measures measure the similarity between two images, hence in this sense they are complementary to the difference based measures. All the correlation based measures tend to 1, as the difference between two images tend to zero. It is calculated using the formula:

$$NK = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[f(i,j).f'(i,j)]}{\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j))^2} \qquad (7)$$

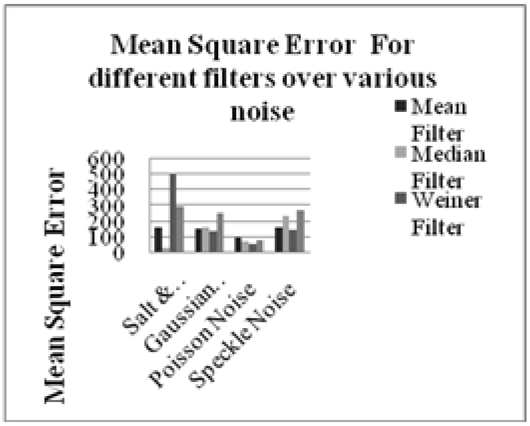

Figure2
MSE value for images subjected to different filters over various types of noise

For image-processing applications in which the brightness of the image and template can vary due to lighting and exposure conditions, the images can be first normalized. This is typically done at every step by subtracting the mean and dividing by the standard deviation. If the normalized cross correlation tends to 1, then the image quality is deemed to be better.

Table III
NK value for images subjected to various filters over different types of noise

Filter/ Noise	Salt & Pepper Noise	Gaussian Noise	Poisson Noise	Speckle Noise
Mean Filter	0.9849	0.9893	0.9937	0.9839
Median Filter	0.9976	0.9966	0.9963	0.9918
Weiner Filter	0.9865	0.9911	0.9962	0.9861
Gaussian Filter	0.9878	0.9922	0.9967	0.9868

Figure 3 shows the graphical representation of Table III. It is seen that NK value of an image subjected to Median filter over all types on noise is near to 1, which is followed by Gaussian filter and Weiner filter and finally the Mean filter shows the poor correlation value over all other types of filters.

D. Normalized Absolute Error

Normalized Absolute Error should be the minimum in order to minimize the difference between original and obtained image. It is calculated using the formula:

$$NAE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left|[f(i,j).f'(i,j)]\right|}{\sum_{i=1}^{M}\sum_{j=1}^{N}|f(i,j)|} \qquad (8)$$

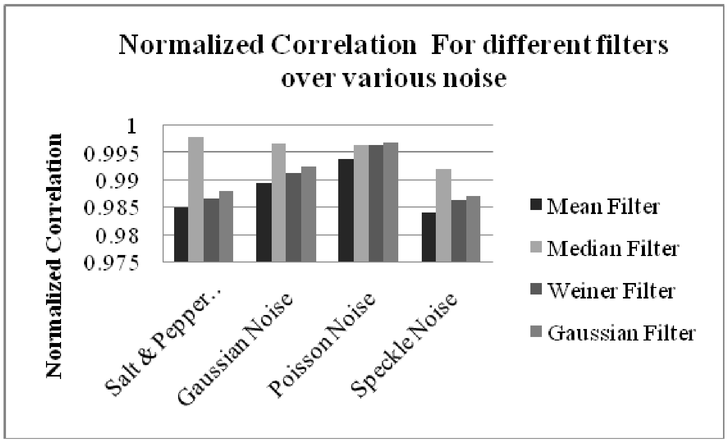

Figure 3
NK value for images subjected to different filters over various types of noise

Normalized absolute error indicates how different both the de-noised image and the original image are with the value of zero being the perfect fit. A large value of NAE represents poor quality of the image.

Table IV
NAE value for images subjected to various filters over different types of noise

Filter/ Noise	Salt & Pepper Noise	Gaussian Noise	Poisson Noise	Speckle Noise
Mean Filter	0.0439	0.0515	0.0374	0.0519
Median Filter	0.017	0.0548	0.0351	0.0661
Weiner Filter	0.0406	0.0508	0.0316	0.0508
Gaussian Filter	0.0291	0.0701	0.0389	0.0734

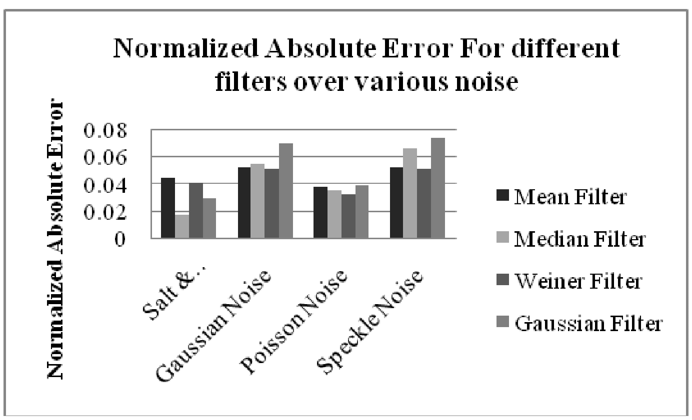

Figure 4
NK value for images subjected to different filters over various types of noise

Figure 4 shows the graphical representation of Table IV. It is seen that NAE value of an image subjected to Median filter over salt and pepper noise have the lowest value; for all other type of noise Image subjected to Weiner filter gives the lowest NAE value. Mean filter shows an average performance over all type noise then followed by Gaussian filter.

V. CONCLUSION

This paper compares the performance of four spatial domain filters mean filter, Median Filter, Gaussian filter and Weiner Filter to De-noise the images subjected to four different types of noise Salt-and-Pepper, Gaussian, Poisson and Speckle noise which can be accumulated during image acquisition phase of Microscopic image processing. From the results shown above it is clear that Median filter shows its best performance over salt-and-pepper noise only and Weiner filter shows good performance over Gaussian, Poisson and Speckle noise. It also shows an optimum performance over salt-and-pepper noise and hence it is concluded that Weiner filter is an optimum filter that can be applied to microscopic images.

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