DE-NOISING FILTERS FOR MICROSCOPIC MEDICAL IMAGES OF HUMAN SPERMATOZOA

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ABSTRACT

Image de-noising is a process of eliminating the unwanted information occupied on the image during image acquisition and image digitization. The noise removal in an image is a challenging pre-process, concern to preserve minute details in the images. The selection of proper noise removal filter will make the sense of retaining the fine details in the image will helpful for feature extraction. Especially in the domain of sperm cell image processing, the better denoising technique is obligatory to maintain the fine details in the image. Generally these images are not clear due to different staining procedures followed during image acquisition. The various emerging noise removal filters are developed for microscopic medical images but they should be identified specifically with respect to the noise in the input image. Most of the microscopic medical images are degraded by Gaussian noise. So that the Gaussian noise is added artificially on the human spermatozoa cell image and de-noised by using several spatial filters. In this paper the performance of various de-noising filters is measured using objective fidelity criteria such as Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and Entropy. This performance analysis moves forward to have further research in denoising for microscopic sperm cell images.

Keywords: *Image De-Noising, Gaussian Noise, Error Metric, Spermatozoa, Infertility*

INTRODUCTION

To determine the male factor infertility and treatment, the morphological structure of human spermatozoa is analyzed [1]. The morphological structure of human spermatozoa in an image can be evaluated with the help of image processing [2, 3]. This kind of objective analysis is always better than the manual evaluation. Sometimes the subjective method of evaluation is failed due to improper guidelines and standards followed in the laboratories. Hence, the stained sperm cell images can be analyzed automatically by the image processing system and gives the report for further treatment.

The sperm cell images are captured by using different equipments. Sometimes these images are affected by unwanted noises due to faulty devices or invalid acquisition and transmission [4]. Therefore, it is highly essential to make the sperm cell images without having any noise. Digital images are spreading its wings to different areas like television, medical imaging, remote sensing, ultra sound and satellite etc. The various image processing systems are used in medical applications such as Computer Tomography (CT), Endoscopy, Ultrasonic imaging system, Magnetic Resonance Imaging (MRI), and Corneal Image Analyzer (CIA). The noise is also a signal may appear on the image as multiplicative or additive components which degrade the quality of an image. So noise removal or noise reduction is an important task in the image processing. Image denoising is the preliminary step should be done before segmentation and feature extraction. Generally the noise can be classified as Gaussian, Rayleigh, Erlang (Gamma), Exponential, Uniform and Impulse noise. All the noises are varied by their probability density function. There is no generic noise removal tool for all kind of noises and also the same method may not work well for the images from different domains such as medical, astronomical, radiographic and satellite. It is a big challenge to identify a denoising filter suitable for all images from one particular domain. Many researchers have implemented various denoising methods for their domain images. In this paper, we have implemented various noise

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removal methods and applied on the Gaussian noised sperm cell images. All the methods have been analyzed based on their performance in removing noise. The schematic diagram of human sperm cell is depicted in Fig.1 and guideline for normal sperm cell (World Health Organization) is shown in Table 1 [6]. The various sections in this paper are as follows. In section 2 Gaussian noise model is explored. Section 3 explains the concept of various filters used for removing Gaussian noise. The objective analysis is required for evaluating the performance of noise removal filters that are provided in Section 4. Section 5 shows the implementation of filters on the noisy images. The conclusion is given in Section 6.

Table 1: World Health Organization's guideline

World Health Organization's guideline for Normal Sperm (5th Edition)	
Volume:	>= 1.5ml
Total Sperm (millions in ejaculate):	>= 39 million is normal
Concentration / Count (millions per ml):	>= 15 million is normal
Motility:	>= 40% is normal
Morphology	>= 30%

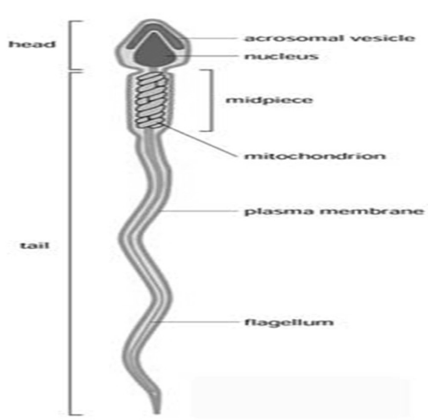

Fig.1: Schematic Diagram of Human Spermatozoa

2. GAUSSIAN NOISE MODEL

The Gaussian noise is an additive noise which may be joined to the original image during digitization of an image. The general noisy image can be modelled as follows

$$g(x, y) = f(x, y) + \eta(x, y) \qquad (1)$$

Where $f(x, y)$ is the original image pixel to be an input, $\eta(x, y)$ is noise and $g(x, y)$ is the output image with noise. It is assumed that the image may be affected by Gaussian noise during digitization [9] so that Gaussian noise is added to the original image and the various spatial smoothing filters are used to remove noise and also preserving the edges in the original image. This process is depicted in the Fig.2.

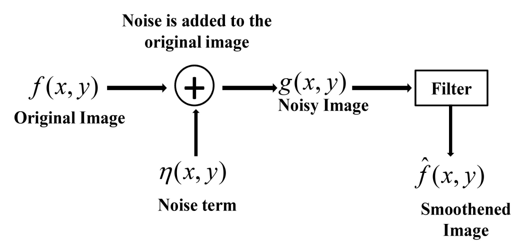

Fig. 2: A model of the Noise addition and smoothing of image

The Gaussian noise is an amplifier noise also known as additive noise, which has a probability density function (PDF) for the normal distribution is shown in Fig.3. This type of noise can be reduced or removed using spatial filters like Mean filter, Geo-Mean filer, Median filter and Gaussian filter and also by using wiener filter. The probability density function of the Gaussian noise is as follows:

$$p(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(z-\mu)^2/2\sigma^2} \qquad (2)$$

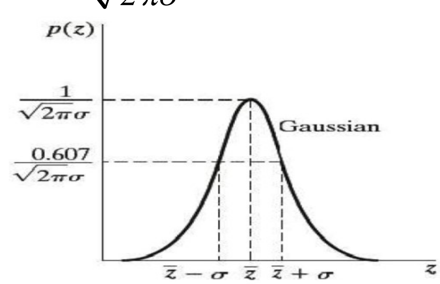

Fig. 3 PDF of Gaussian Noise

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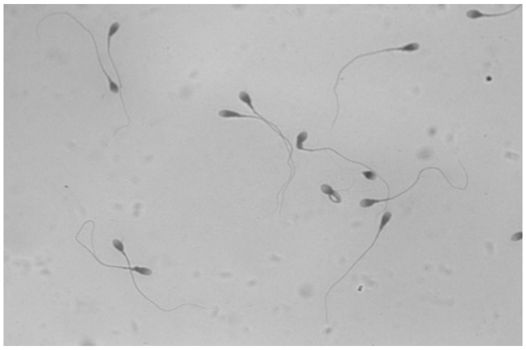
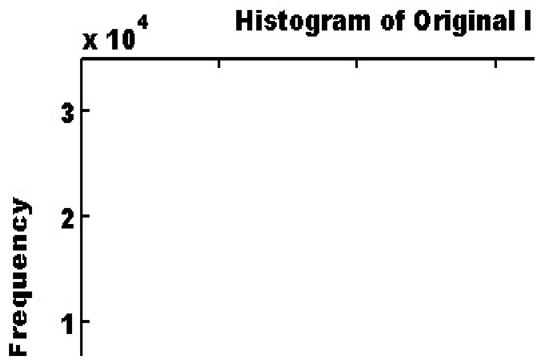
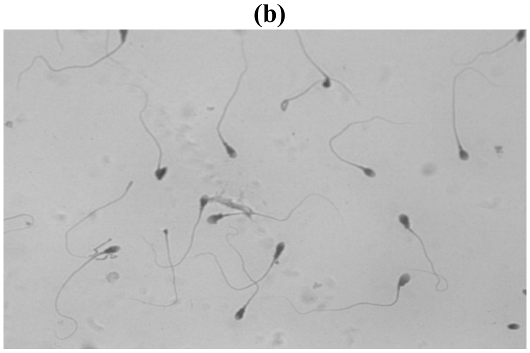


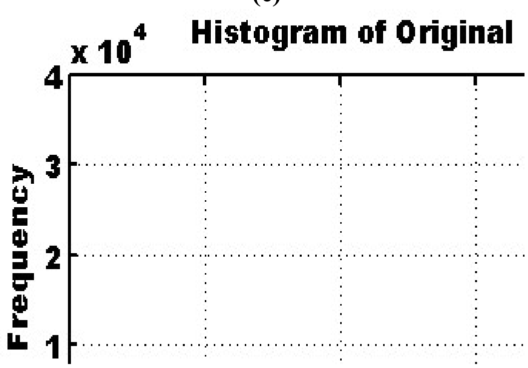
(a)



(b)



(c)



(d)

Fig. 4: Original images of human spermatozoa and its histogram (a):Original image–1 (b):Histogram of Original image-1 (c):Original image-2 (d): Histogram of Original image-2

3. DENOISING FILTERS

Image denoising can be done in frequency domain and spatial domain. In frequency domain the signals of an image can be processed whereas in spatial domain the pixels are processed directly. The denoising techniques are based on the amount of noise and type of noise in the input image. Normally the Gaussian noise is affecting the images during digitization. Hence, the filters which are reducing or removing the Gaussian noise that are compared with relevant metrics. The spatial filters such as Gaussian filter, Mean filter,

Geo-Mean filter, Median filter and Wiener filter are effectively removing the Gaussian noise but they are differed in preserving the information in the image.

3.1 Gaussian filter:

It is a linear filter, pass high frequency values (low pass filter) and blurring the image. This filter is removing the Gaussian noise and not removing the impulse noise effectively [7]. The Gaussian filter will remove Gaussian noise from the affected image. The formula for Gaussian filter is given below.

$$g(x, y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{3}$$

This non-uniform low pass filter is based on its kernel coefficients. The larger value of σ will blur the image greater. Gaussian filters might not preserve image brightness.

3.2 Mean Filters:

The Arithmetic mean, Geometric mean, Hormonic mean, Contrahormonic mean are the types of mean filters used for reducing the noise in the image. In this paper the arithmetic mean and geometric mean is applied on the noisy image. The geometric mean filter has given better result in smoothing the microscopic images. These filters will reduce Gaussian noises in an image.

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3.2.1. Arithmetic mean filter:

This filter window will replace the center coefficient in the window with average mean of all the pixels in the kernel. Arithmetic mean filter is calculated as follows.

$$\hat{f}(x,y) = \frac{1}{mn} \sum_{(s,t)\in S_{xy}} g(s,t) \tag{4}$$

3.2.2. Geometric mean filter:

This filter works as like arithmetic mean but lose less image information. It is a kind of non-linear mean filter aims to reduce or remove Gaussian noise in the image as follows.

$$\hat{f}(x,y) = \left[\prod_{(s,t)\in S_{xy}} g(s,t) \right]^{\frac{1}{mn}} \tag{5}$$

3.3. Median filter:

It is a type of order statistics filter tends to reduce Gaussian noise effectively in the image. This filter will change the pixel value of the image with median value. This filter will arrange the pixels in the image in ascending order then replace the pixel with median value. If there is no median value then the average of two middle pixel values are calculated and updated in the image. This filter is also reducing the Gaussian noise in the image. It is calculated as follows.

$$\hat{f}(x,y) = \underset{(s,t)\in S_{xy}}{median} \{g(s,t)\} \tag{6}$$

3.4. Wiener filter:

The Wiener filter works well in removing additive noise in the image and also inverts the blur. This filter follows stochastic approach so that the linear estimation of an image is considered. The wiener filter will reduce mean square error while smoothing the image. This filter is given below.

$$W(u,v) = \frac{H^*(u,v) s_{xx}(u,v)}{|H(u,v)|^2 S_{xx}(u,v) + s_{\eta\eta}(u,v)} \tag{7}$$

The power spectra for the original image are $s_{xx}(u,v)$ and $s_{\eta\eta}(u,v)$ with additive noise and $H(u,v)$ is blurring filter. Here the Wiener filter has inverse filter and noise smoothing part. It executes inverse filtering to achieve deconvolution and performs compression to remove noise.

4. OBJECTIVE FIDELITY CRITERIA

The manipulation of an image may lead to information lose. Sometimes it is difficult to identify the information lose in the image. So the objective method of error checking is helpful for understanding the modifications in the image.

4.1. Mean Square Error (MSE):

It is used to compare the original image and filtered image. The MSE is the sum of squared error between original and filtered image. The lesser value of MSE means lesser error in the image. The formula for MSE is as follow

$$\text{MSE}=\frac{1}{MN}\sum_{y=1}^{M}\sum_{x=1}^{N}[I(x,y)-I'(x,y)]^2 \tag{8}$$

4.2. Peak Signal to Noise Ratio (PSNR):

It is opposite to MSE, higher value of PSNR means signal to noise ratio is higher. The signal is original image and noise is filtered image. Hence the MSE value should be low and PSNR value should be high for the image filtering. The formula for PSNR is given below

$$\text{PSNR}= 20 * \log_{10}\left(\frac{255}{\sqrt{(MSE)}}\right) \tag{9}$$

4.3. Entropy:

Entropy is nothing but a statistical measure of randomness of an image. This method of quality measurement is helpful for getting the texture of the input image. This method of quality metric is used in microscopic medical images. Entropy is given below

$$Entropy = -\sum_{r=1}^{M-1}\sum_{s=1}^{N-1} P(r,s)\log P(r,s) \tag{10}$$

Where P(r, s) is the probability of the pixel(r, s) occurs.

4.4. Kurtosis:

A statistical description of an image can be given by mean, median, mode, variance, standard deviation, entropy and kurtosis, which are useful for analyzing the probability distribution of gray images. The kurtosis measures whether the shape of probability distribution is peak or flat. For comparing the shape of histogram of one image with another, the kurtosis value is taken for both

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images and then compared. If the kurtosis value of de-noised image is greater than the kurtosis value of noised image then it is confirmed that the de-noising filter has reduced the noise in the noisy image effectively. The kurtosis is calculated based on the probability of pixels, mean and standard deviation of an image. The kurtosis is as follows

$$\text{Probability of pixels } P(b) = \frac{H(b)}{M} \quad (11)$$

where H(b) is histogram for every pixel in an image and probability is calculated by dividing the frequency of every pixel by total number of pixels (M). After getting P(b) it is necessary to get mean and standard deviation for an image is as follows.

$$\text{Mean} = \sum_{b=1}^{L} b.P(b) \quad (12)$$

is the Sum of product of ‘b’ and probability of each pixel. Here ‘b’ is a gray level between 1 and 255. The Standard Deviation is calculated for the same image is as follows.

$$SD = \sqrt{\sum_{b=1}^{L} (b - mean)^2 .P(b)} \quad (13)$$

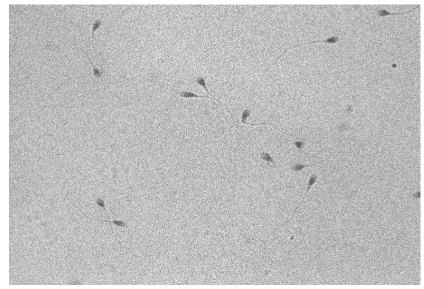
SD is standard deviation is calculated based on the subtraction of mean from gray level ‘b’ and multiplied with probability of pixel ‘b’ where ‘b’ is between 1 and 255. Finally the SD is obtained by getting Root for the sum. The kurtosis is finally obtained by the formula is given below.

$$\text{Kurtosis} = \frac{1}{(SD)^4} \sum_{b=1}^{L} (b - mean)^4 .P(b) \quad (14)$$

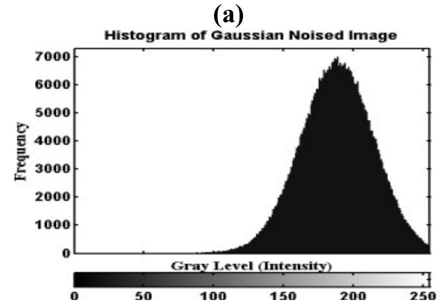
the fourth order moment of kurtosis is calculated by using the values of standard deviation, mean and probability of frequency of every pixel.

5. IMPLEMENTATION AND ANALYSIS

Experiments were conducted on microscopic images of human spermatozoa in RGB color space. The original images were acquired by the authors of [5] based on the gold-standard available online [8]. We have used the sample sperm cell images taken from the gold-standard database, and without converting them from RGB color space to any other color spaces. The Figs. 4(a & c) are the original images of human spermatozoa. The histogram is taken for the original images. The x-axis value is between 0 and 255 as gray level (intensity) and y-axis is considered as frequency with value between 0 and 40000. The histograms for original images are shown in Figs.4 (b & d) which shows that the histogram is spanned between 150 and 240 gray values.

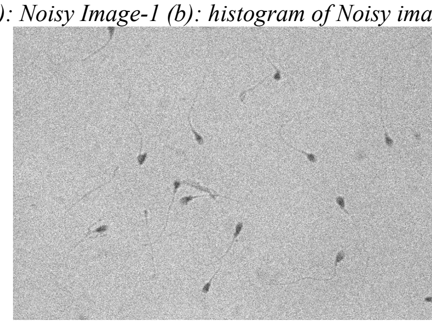


(a)

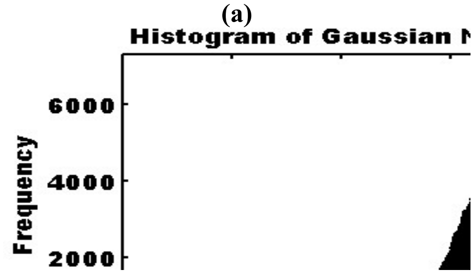


(b)

Fig.5: Gaussian noise is added to the Original image-1 and its histogram
(a): Noisy Image-1 (b): histogram of Noisy image-1



(a)



(b)

Fig.6: Gaussian noise is added to the Original image-2 and its histogram
(a): Noisy Image-2 (b): histogram of Noisy image-2

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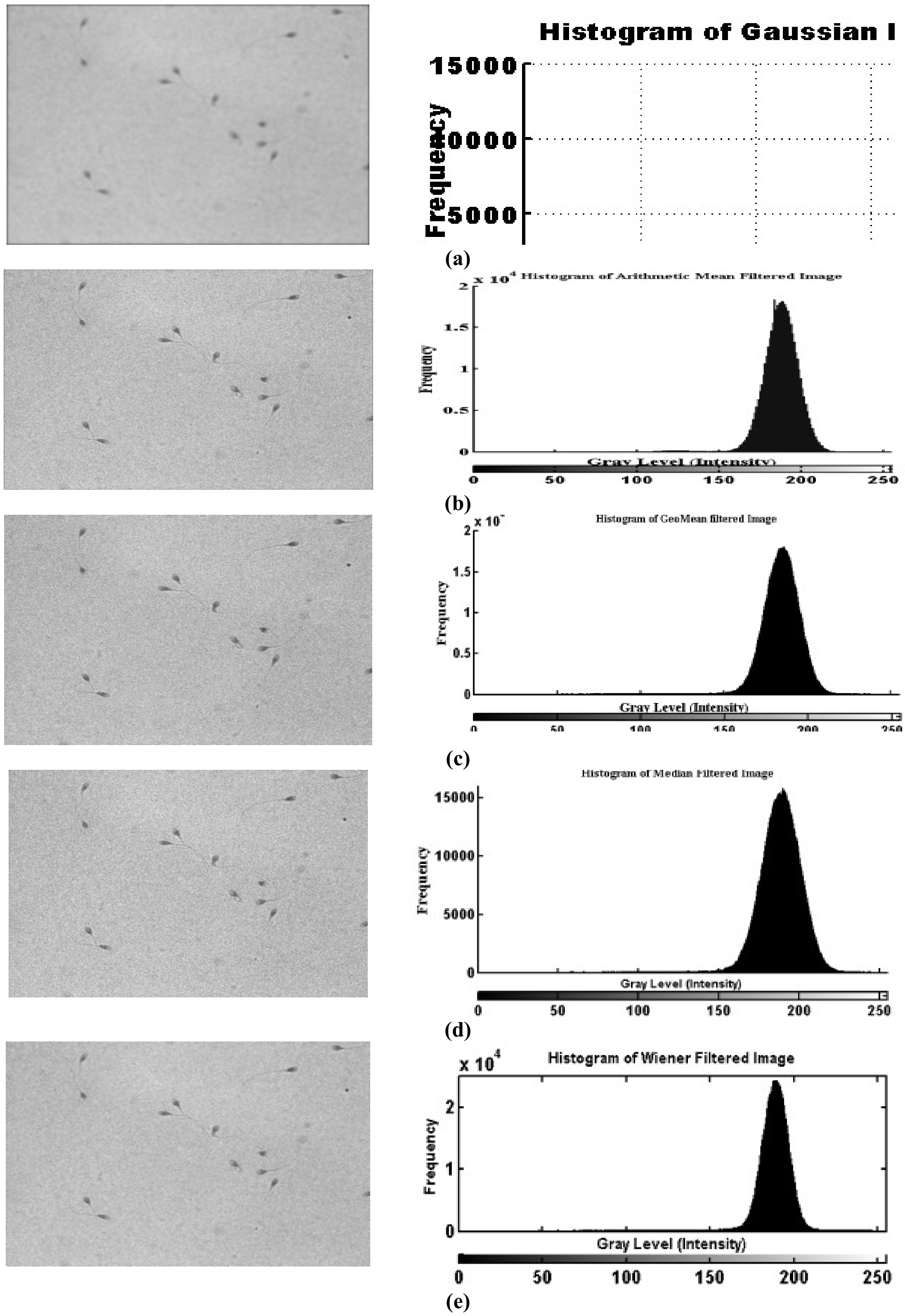

Fig.7: Various filters applied on the Noisy image-1 and its relevant histogram;
(a): Gaussian Filter (b): Arithmetic Mean Filter (c): GeoMean Filter (d): Median Filter (e): Wiener Filter

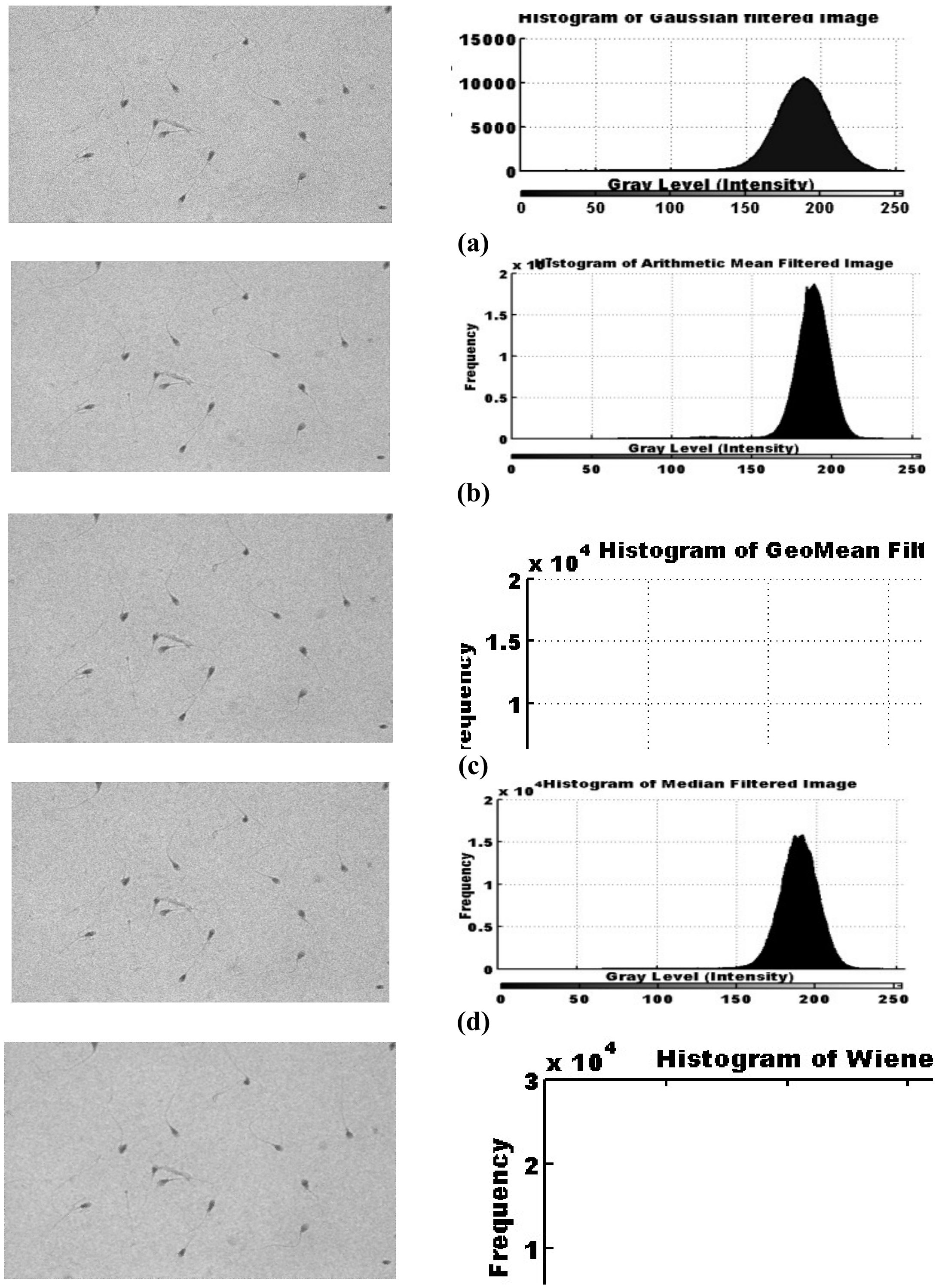

Fig.8: Various filters applied on the Noisy image-2 and its relevant histogram; (a): Gaussian Filter (b): Arithmetic Mean Filter (c): GeoMean Filter (d): Median Filter (e): Wiener Filter

The histogram is the pictorial representation of number of occurrences of every pixel (frequency) in the image. In the histogram x-

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axis specifies gray level in the image and y-axis specifies frequencies. The histogram is taken for the original images before denoising process.

The Gaussian noise is an additive noise which may affect the microscopic medical images during digitization. So that the simulated Gaussian noise is added purposely to the original images then they become Noisy images which are shown in Fig.5(a) & Fig.6(a). The Fig.5(b) and Fig.6(b) are the respective histogram for noisy images. Both histograms are showing bell shaped Gaussian noise clearly. Later the noise is reduced and removed using various filters which are depicted in Fig. 7 and Fig.8. Based on the studies of the various researchers in the field of medical image processing, it is identified that the Gaussian noise can be reduced or removed effectively with the help of averaging filters, median filter and wiener filter. The process of adding noise to the original image and removing noise from the original image is implemented using MATLAB R2010a software. The original image is noised with simulated Gaussian noise with variance 0.01 (1% of noise).The noised image then filtered by various noise removal filters. There are many noise removal filters implemented effectively in various domains, but all the filters are not filtering the noise effectively. It is only because of the images which are captured by using different kind of devices.

The image in the domain of spermatozoa is visualized by using microscope and other electronic devices. These images will be affected by Gaussian noise. Hence we have considered the filters which are reducing or removing Gaussian noise in the original image. The spatial filters such as Gaussian filter, arithmetic mean filter, median filter, geo mean filter and wiener filter are blurring or smoothening the original image. These filters can reduce the noise in the original image but they are varied in the level of noise reduction. After using the spatial filters on the noised image, the image may lose some features. So it is important to identify the apt filter to reduce noise without losing any information. After the noise removal process the visual quality of the image is improved as well as the noise is also reduced. The manual visual evaluation is always subjective so that the objective measuring is considered to analyze the performance of each filter.

In this paper, the various objective error measuring metrics have been used to evaluate the performance of various filters. The metrics we have followed is (MSE) Mean Square Error, (PSNR) Peak Signal-to-Noise Ratio, Entropy and Kurtosis. The filtered images are compared with original images by using the above specified objective fidelity metrics. The kurtosis is a statistical measurement was used on the noised images and de-noised images for analyzing the shape of probability distribution. The kurtosis value of all filtered images was greater than the kurtosis value of noised images. It is meant that the filters have reduced the noise in the noisy images. It is important to specify the filter which is better than the other filters. The detail is given in Table 4. Based on the result of objective fidelity evaluation, the Wiener Filter has removed the simulated additive noise in the sperm cell images effectively. The other filters such as Gaussian filter, Mean filter, Median filter and Geo-Mean filter reduced the noise but the ratio of blurring the image is high which leads to information lose. The lowest MSE value and Highest PSNR value of the evaluation is proved that the noise is removed effectively from the image. In this evaluation the wiener filter has got MSE as 55.7784 and PSNR as 30.6661 for the original image-1.

In the original image-2 the MSE value is 56.4804 and PSNR value is 30.6118. The entropy based evaluation is also helpful for understanding the modification in the image after removing the noise. The entropy of wiener filtered image is less than the entropy of other filtered images.

The entropy of wiener filtered image is 3.50589137432143 with respect to original image-1 and 3.47159482028 with respect to original image-2. These details are shown in Table 2 and Table 3. Hence it is understood that the wiener filter has reduced the noise in the image which is the better performance among the other filters.

Table.2. Objective fidelity criteria for the filtered images

Name of the Filter applied on the noisy Image-1	Filtered image compared with Original Image – 1		
	MSE	PSNR	Entropy
Gaussian Filter	90.7964	28.5501	3.55070157766187
Median Filter	122.5754	27.2468	3.91186920313854
Wiener Filter	55.7784	30.6661	3.50589137432143
Arithmetic Mean Filter	100.9265	28.0908	3.76171021090692
Geometric Mean Filter	82.7619	28.9525	3.76479466889051

Table.3. Objective fidelity criteria for the filtered images

Name of the Filter applied on the noisy Image-2	Filtered image compared with Original Image – 2		
	MSE	PSNR	Entropy
Gaussian Filter	269.0237	23.8329	4.28966920830
Median Filter	122.5526	27.2476	3.90360086459
Wiener Filter	56.4804	30.6118	3.47159482028
Arithmetic Mean Filter	100.8223	28.0952	3.75543916110
Geometric Mean Filter	82.6978	28.9559	3.75060009325

Table.4. Statistical analysis of Pixel distribution for filtered images

Histogram detail	Kurtosis value
Noised Image -1	**3.13964**
Wiener filtered image	***18.0704***
Arithmetic Mean filtered image	12.21833
Geomean filtered image	10.48326
Median filtered image	7.51989
Gaussian Filtered image	4.66014
Noised Image -2	**3.29893**
Wiener filtered image	***23.97104***
Arithmetic Mean filtered image	14.73999
Geomean filtered image	14.15165
Median filtered image	9.91486
Gaussian Filtered image	4.0122

6. CONCLUSION:

In this paper, the Gaussian noise was added to the microscopic images of human spermatozoa and the same was removed using Gaussian filter, Wiener filter, Arithmetic mean filter, Geo metric Mean filter and Median filter. The performance of all filters was evaluated based on Mean Square Error, Peak Signal to Noise Ratio, Entropy and Kurtosis. The report shows that the wiener filter showed better performance in removing Gaussian noise in both noisy images of microscopic image domain but, this result may be varied for the images in other domains. Future scope of this work will make some sense in developing better tool for removing noise of various types degrading microscopic sperm cell images.

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