Impact & Analysis of Hybrid Median Filter on TEM Images

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Abstract:
TEM images are rapidly gaining prominence in various sectors like life sciences, pathology, medical science, semiconductors, forensics, etc. Hence, there is a critical need to know the effect of existing image restoration and enhancement techniques available for TEM images. This paper focuses on Hybrid Median Filter. The simulation is carried on greyscale and colored TEM images separately. To do so different types of noise (Gaussian Noise, Salt & Pepper Noise, Salt & Pepper Noise & Poisson Noise) is incorporated into image. Each degraded image is denoised by filters. The result is analyzed on the basis of four parameters namely mean of the image, mean square error, signal to noise ratio, peak signal to noise ratio respectively. This paper also notices the effect on TEM image with changing window size of hybrid median filter.

Keywords: TEM Image, Hybrid Median Filter, Noise, Window size

I. Introduction

TEMs are capable of imaging at a significantly higher resolution than light microscopes, owing to the small de Broglie wavelength of electrons. This enables the instrument's user to examine fine detail even as small as a single column of atoms, which is tens of thousands times smaller than the smallest resolvable object in a light microscope. TEM forms a major analysis method in a range of scientific fields, in both physical and biological sciences. At smaller magnifications TEM image contrast is due to absorption of electrons in the material, due to the thickness and composition of the material. At higher magnifications complex wave interactions modulate the intensity of the image, requiring expert analysis of observed images.

Compared to the vast amount of research in medical imaging modalities such as MRI and CT, the number of scientific papers on electron microscopy applications in the image processing community has been very limited. A microscopy image gets corrupted by noise, which may arise in the process of acquiring the image, or during its transmission, or even during reproduction of the image.

II. Hybrid Median Filter

In median filtering, the neighboring pixels are ranked according to brightness (intensity) and the median value becomes the new value for the central pixel. Median filters can do an excellent job of rejecting certain types of noise, in particular, “shot” or impulse noise in which some individual pixels have extreme values. Median filters can tend to erase lines narrower than ½ the width of the neighborhood. They can also round off corners.

Hybrid median filters can get around these problems. The hybrid median filter is a three step ranking process that uses two subgroups of a 5x5 neighborhood. These subgroups are drawn from pixels parallel to the image frame edges, and at 45º to the edges, centered on the reference pixel [6].

B = hmf(A,n) performs hybrid median filtering of the matrix A using a n x n box. Hybrid median filter preserves edges better than a square kernel median filter because it is a three-step ranking operation: data from different spatial directions are ranked separately[3]. Three median values are calculated: MR is the median of horizontal and vertical R pixels, and MD is the median of diagonal D pixels. The filtered value is the median of the two median values and the central pixel C: median([MR,MD,C]) [5]. As an example, for n = 5:

$$\begin{bmatrix} D & * & R & * & D \\ * & D & R & D & * \\ R & R & DCR & R & R \\ * & D & * & D & * \\ D & * & R & * & D \end{bmatrix}$$

Fig 1. Median Calculation

III. Noise in TEM Image

Noise is defined as an unwanted component of the image. Noise occurs in images for many reasons. Noise can generally be grouped into two classes, independent noise & the noise which is dependent on the image data.

i) Gaussian Noise

Gaussian noise is characterized by adding to each image pixel a value from a zero-mean Gaussian distribution. The zero mean property of the distribution allows such noise to be removed by locally averaging pixel values [1]. Noise is modelled as additive white Gaussian noise (AWGN), where all the image pixels deviate from their original values following the Gaussian curve. That is, for each image pixel with intensity value Oij ($1 \le i \le M$, $1 \le j \le N$ for an M x N image), the corresponding pixel of the noisy image Xij is given by,

$$Xij=Oij+Gij \quad (1)$$

where, each noise value G is drawn from a zero –mean Gaussian distribution. Gaussian noise can be reduced using a spatial filter. However, it must be kept in mind that when smoothing an image, we reduce not only the noise, but also the fine-scaled image details because they also correspond to blocked high frequencies.

ii) Poisson Noise

Poisson noise, is a basic form of uncertainty associated with the measurement of light, inherent to the quantized nature of light and the independence of photon detections. Its expected magnitude is signal-dependent and constitutes the dominant source of image noise except in low-light conditions. The magnitude of poisson noise varies across the image, as it depends on the image intensity [2].

iii) Salt & Pepper Noise

Another common form of noise is *data drop-out* noise (commonly referred to as *intensity spikes*, *speckle* or *salt and pepper noise*). Here, the noise is caused by errors in the data transmission. The corrupted pixels are either set to the maximum value (which looks like snow in the image) or have single bits flipped over. In some cases, single pixels are set alternatively to zero or to the maximum value, giving the image a `salt and pepper' like appearance. Unaffected pixels always remain unchanged. The noise is usually quantified by the percentage of pixels which are corrupted [2].

iv) Speckle noise

Increase in power of signal and noise introduced in the image is of same amount that is why speckle noise is termed as multiplicative noise [3]. It is signal dependent, non-Gaussian & spatially dependent. Due to microscopic variations in the surface, roughness within one pixel, the received signal is subjected to random variations in phase and amplitude. The variations in phase which are added constructively results in strong intensities while other which are added destructively results in low intensities. This variation is called as Speckle [1].

IV. Working Methodology

The complete simulation is carried in Matlab. Two original microscopic images, one greyscale and one colour, are taken. Noise is added to the original image. Four types of noises are added namely gaussian noise, speckle noise, salt & pepper noise & poisson noise respectively. This distorted image is then filtered using Hybrid Median Filter algorithm and is also analyzed with changing window size as shown in Fig.2.

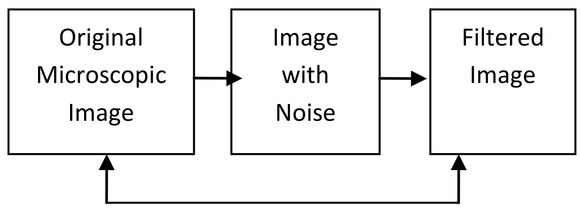


Fig. 2. Working Methodology

V. Implementation of Hybrid Median Filter

i) For color TEM image

Window Size	Mean	MSE	SNR	PSNR
Gaussian Noise				
3	169.716	142.053	12.184	26.606
5	169.651	114.814	12.644	27.530
7	169.612	100.183	12.939	28.122
Speckle Noise				
3	167.717	13.5681	17.273	36.805
5	167.681	14.1513	17.181	36.622
7	167.645	16.0291	16.909	36.081
Salt & Pepper Noise				
3	167.861	23.183	16.111	34.479
5	167.792	16.623	16.832	35.923
7	167.734	14.524	17.124	36.509
Poisson Noise				
3	167.736	23.921	16.043	34.343
5	167.695	22.355	16.188	34.636
7	167.655	22.945	16.131	34.523

Table1. Simulation Results with varying Window Size for colored TEM image

ii) For greyscale TEM image

Window Size	Mean	MSE	SNR	PSNR
Gaussian Noise				
3	221.0272	3.57E+03	5.8168	12.6005
5	221.3432	3.46E+03	5.8858	12.7386
7	221.5175	3.39E+03	5.9286	12.8249
Speckle Noise				
3	221.8892	3.67E+03	5.7815	12.4893
5	222.1347	3.56E+03	5.8462	12.6212
7	222.3019	3.49E+03	5.8871	12.7043
Salt & Pepper Noise				
3	223.7385	3.83E+03	5.723	12.2968
5	224.0137	3.73E+03	5.7825	12.4172
7	224.1967	3.66E+03	5.8205	12.4937
Poisson Noise				
3	221.7959	3.66E+03	5.7843	12.4986
5	222.0618	3.55E+03	5.8485	12.6287
7	222.2294	3.48E+03	5.8888	12.7103

Table2. Simulation Results with varying Window Size for greyscale TEM image

As shown in table 1 and table 2 for both type of images for gaussian noise hybrid median filter performed well. Higher kernel size gave the desired performance for salt & pepper noise for both types of images. For speckle noise low size kernel for colored image and higher sized kernel for greyscale image gave the required result. For poisson noise window size=5 gave better performance while for greyscale image window size =7 proved better.

VI. Conclusion

Simulation results are shown in figure 3which clearly indicates that Hybrid Median Filter not only performed well for salt & pepper noise but also performed well enough on other types of noise.

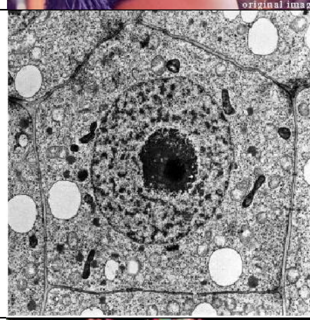
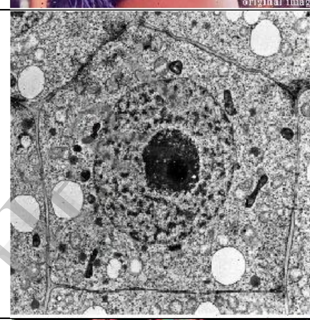
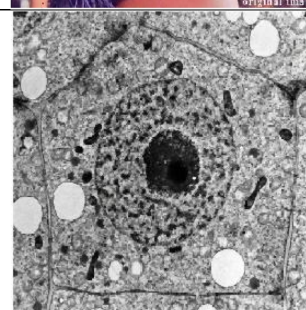
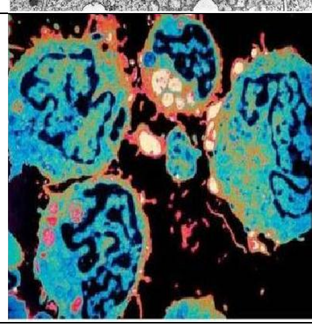
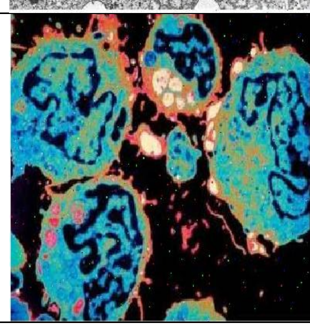
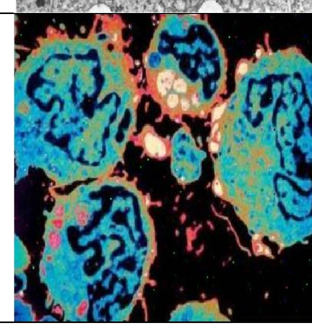
HYBRID MEDIAN FILTER			
	Original Image	Noisy Image	Filtered Image
Greyscale Normal Image			
Greyscale Colored Image			
Greyscale TEM Image			
Colored TEM Image			

Fig.3. Simulation Results

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