A DETAILED ANALYSIS OF VARIOUS DENOISING TECHNIQUES FOR CDNA MICROARRAY IMAGES

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ABSTRACT

The image noises usually occur during the accusation or while transmission. It is necessary to remove the noise to provide further processing techniques like edge detection, segmentation, etc. In this paper the analysis is performed to remove salt and pepper noise, Gaussian noise and speckle noise using different Denoising techniques like standard median filter (MF), switched median filter (SMF), Progressive Switched Median Filter(PSMF), vector median filter (VMF), Decision Based Algorithm (DBA), Mean Filter, Weiner Filter (WF) and Wavelet based denoising using different coefficients are implemented.

The scope of the paper is to find better denoising method. The MATLAB based simulation is carried out for calculating the Mean square Error (MSE), Peak Signal to noise ratio (PSNR) and Mean Structural Similarity Index (MSSIM) values. The result obtained using Switched Median Filter and Decision Based Algorithm is performs better in removing Salt and Pepper Noise. Similarly for removing Gaussian noise and Speckle Noise by Wavelet transform.

Keywords- Gaussian Noise, Mean Square Error (MSE), Mean Structural Similarity Index (MSSIM), Peak Signal To Noise Ratio (PSNR), Salt And Pepper Noise And Speckle Noise

I. INTRODUCTION

The microarray image is considered to be the next generation development in bioinformatics to monitor thousands of genes simultaneously. A microarray image is an array of spots sequences arranged in the solid surface of glass slide. Every spots contains multiple collection of single DNA sequence [1].

During the process of experiment the mRNA of the two tissue of interest is extracted and purified, then each of the mRNA samples are reverse transcribed into its complementary Deoxyribonucleic acid (cDNA). They are labeled with two different fluorescent dyes which results into two fluorescence tagged cDNA (green CY3, red CY5). The tagged cDNA are hybridized in the glass slides.

The hybridized glass slide with fluorescent dyes is scanned at different wavelength where two different images are obtained. In the microarray image noise originates from different sources during the process of experiment, electronic noise, dust on the glass slide, due to laser light reflection and so on. Hence it is necessary to remove the noise for further processing [2-6].

In this paper a detailed comparative analysis of different Denoising techniques is implemented to remove salt and pepper noise, Gaussian noise and speckle noise.

II. TYPES OF NOISE.

2.1 Salt and Pepper Noise

The salt and pepper noise is also called as impulse noise or spike noise. A typical variety of salt and pepper noise in a cDNA microarray image is the salt and pepper noise which will have dark pixel in bright region and bright pixel in dark region. The white pixel (salt) and black pixel (pepper) is the kind of disturbance to the image. The noise density can be that of the salt and pepper noise in the image. The total noise density of nd in an M×N image is nd×M×N pixel contains noise. In general, the complete noise density of salt and pepper is d then every salt noise therefore the pepper noise is nd/2. The salt noise and pepper noise is different noise density nd1 and nd2, therefore the whole noise density will be:

$$nd = nd1 + nd2 \qquad (1)$$

2.2 Speckle Noise

The in cDNA microarray imaging technique speckle noise will be present so it is necessary to remove the speckle noise. Speckle noise is considered to be multiplicative noise can be represented by the equation as below:

$$N(i,j)=nf(i,j)m(i,j)+a(i,j) \qquad (2)$$

were n(i,j) represents the noisy pixel, nf(i,j) is considered to be noise free pixel, m(i,j) is the multiplicative noise and a(i,j) is the additive noise respectively i, j are the spatial locations. Since the effect of additive noise is considerably small when compared with multiplicative noise (2) we can write as:

$$n(i,j) = nf(i\ j)\ m(i,j) \qquad (3)$$

Where the speckle noise intensity nf(i,j) m(i,j) is close to Gaussian noise. The logarithmic transform of multiplicative form equation in (3) to additive noise is as:

$$\log n(i,j) = \log nf(i,j) + \log m(i,j) \qquad (4)$$

$$x(i,j)=y(i,j)+n(i,j) \qquad (5)$$

were log n(i,j) is the noisy image in the cDNA microarray image after the logarithmic compression is denoted as x(i,j) and the log nf(i,j) ,log m(i,j) are the noise free pixel and the noisy component after the logarithmic compression is y(i,j) n(i,j).

2.3 Gaussian noise

Gaussian noise is an additive in nature`, and it follows Gaussian distribution where each pixel in the noisy image is the sum of the real pixel value and random, Gaussian distributed noise value. The noise is independent of intensity of pixel value at each point in the image.

III. STANDARD MEDIAN FILTER

The non-linear filter is widely used to remove noise in an image than the linear filtering techniques because linear filtering technique will tend to remove the fine details of the image [7-12]. The standard median filtering method for the image window size taken is 3×3 where the noise and the noise free pixels are in the window. The median value is considered in order to replace the noisy pixel to noise free pixel.

The detection of noisy pixel and noise free pixel are by considering the value of the processed pixel values which is between maximum and minimum value with in the selected window. The dynamic range of the impulse noise is (0, 255). When the value is of the range (0, 255) it is considered to be corrupted by the impulse noise and the remaining pixels are the same [10].

If the dynamic range of the pixel is not between (0, 255) then it is a noisy pixel and it is replaced by the median value or the neighborhood value of the window. By replacing the median value of each window the impulse noise is removed. Hence we get a noise free image. Similarly the Gaussian noise and speckle noise is removed with the standard median filter.

3.1 Algorithm for Standard Median Filter.

STEP 1: Read the noisy image I.
STEP 2: Convert the color image to gray scale image G.
STEP 3: Pad G matrix with zeros at the boundaries to get matrix P
STEP 4: Taking 3×3 matrix of pixel from matrix P.
STEP 5: Arranging the pixel in ascending order from the 3×3 matrix.
STEP 6: Calculate the median pixel and replace in matrix B.
STEP 7: Repeat step 6 for the entire image.
STEP 8: Display the denoised output image.
STEP 9: Calculate the MSE, PSNR and MSSIM value.

IV. SWITCHED MEDIAN FILTER

The switched median filter (SMF) is popularly used to remove the impulse noise. The SMF will provide better denoising in an image [12-14]. The switched median filter it switches for the certain condition. We take the window size to be 3×3 in the matrix. Then we calculate the maximum value in the window Wmax, the minimum value Wmin and the median value M.

When Wmin<M && M< Wmax, if this condition satisfies then we replace the fifth value in the window if not the condition is checked if it is satisfied then the median value is replaced or else the mean value of the window is replaced. The switching median filter will remove the impulse noise, Gaussian noise and the speckle noise.

4.1 Algorithm for Switched Median Filter

STEP 1: Read the noisy image I.

STEP 2: Convert the color image to gray scale image G.

STEP 3: Pad G matrix with zeros at the boundaries to get matrix P

STEP 4: Taking 3×3 matrix of pixel from matrix P.

STEP 5: Calculate maximum pixel in the window W_{max}.

STEP 6: Calculate minimum pixel in the window W_{min}.

STEP 7: Calculate median in the window M.

STEP 8: Check the condition

Case A: If W_{min}<M && M< W_{max} put B(i,j)=0, then move to step9.

Case B: If Wmin<M && M< Wmax put B(i,j)=M, then move to step 9.

Case C: If Wmin<M && M< Wmax put B(i,j)=mean of window, then move to step9

STEP 9: Repeat step 8 for the entire image.

STEP 10: Display the denoised output image.

STEP 11: Calculate the MSE and PSNR value.

V. PROGRESSIVE SWITCHED MEDIAN FILTER

The Progressive Median Filter [15] initially the two image sequences are generated during the impulse detection procedure. The first is a sequence of gray scale images represented as {$\{X_i^{(0)}\}$, $\{X_i^{(1)}\}$,…… $\{X_i^{(n)}\}$ ….}, and binary image represented as {$\{F_i^{(0)}\}$, $\{F_i^{(1)}\}$,…… $\{F_i^{(n)}\}$ ….}. If $F_i^{(n)}=0$ it is noise free, $F_i^{(n)}=1$ it is noisy. For $X_i^{(n-1)}$ median value 3x3 window $M_i^{(n-1)}$ = Med $X_j^{(n-1)}$. Compute difference for $X_i^{(n-1)}$ and $M_i^{(n-1)}$,i.e. |Xi(n-1) - Min(n-1)| < TD. In order to detect weather it is impulse or not the binary value of the flag should be as given in the equation 7.1.

$$F_i^{(n-1)} = \begin{cases} F_i^{(n-1)}, & \left|X_i^{(n-1)}\ M_i^{(n-1)}\right| < TD \\ 1, & otherwise \end{cases} \tag{6}$$

The threshold, TD is a pre-defined value. If $F_i^{(n-1)}$ < TD is noise free otherwise it is considered as noisy. When the impulse is detected the $X_i^{(n)}$ is modified as in equation 7.2.

$$X_i^{(n)} = \begin{cases} M_i^{(n-1)}, & F_i^{(n)} \neq F_i^{(n-1)} \\ X_i^{(n-1)}, & F_i^{(n)} = F_i^{(n-1)} \end{cases} \tag{7}$$

The $Xi^{(n)} = M_i^{(n-1)}$ N iteration is done or the same input pixel is replaces as $X_i^{(n)} = X_i^{(n-1)}$ there by this procedure the impulse detection is completed.

The second procedure is the Noise filtering the gray scale image is considered as {$\{Y_i^{(0)}\}$, $\{Y_i^{(1)}\}$,…… $\{Y_i^{(n)}\}$ ….} and binary image as {$\{G_i^{(0)}\}$, $\{G_i^{(1)}\}$,…… $\{G_i^{(n)}\}$ ….} If $G_i^{(n)}=0$ is noise free, $G_i^{(n)}=1$ is noisy. For $Y_i^{(n-1)}$ the median value is selected for 3x3 window $M_i^{(n-1)}$=Med $Y_i^{(n-1)}$. Median is calculated for number of pixel in the image. Replacing the value of the flag as zero and iterating to N times the noise is removed. In case if the impulse is obtained again then the $Y_i^{(n)}$ is modified as in equation 7.3.

$$Y_i^{(n)} = \begin{cases} M_i^{(n-1)}, & if\ G_i^{(n-1)} = 1 \\ Y_i^{(n-1)}, & otherwise \end{cases} \quad (8)$$

The Progressive Median Filter will remove the impulse noise effectively when compared to that of the Median Filter.

5.1 Algorithm for Progressive Switched Median Filter

STEP1: Read image I

STEP2: Convert I to gray scale G.

STEP3: Detecting image as gray scale $\{\{X_i^{(0)}\}, \{X_i^{(1)}\}, \ldots\ldots \{X_i^{(n)}\} \ldots.\}$ and binary $\{\{f_i^{(0)}\}, \{f_i^{(1)}\}, \ldots\ldots \{f_i^{(n)}\} \ldots.\}$

STEP4: The $f_i^{(n)}=0$ it is noise free, $f_i^{(n)}=1$ it is noisy.

STEP5: For $X_i^{(n-1)}$ median value 3x3 window $m_i^{(n-1)}=med\ X_j^{(n-1)}$.

STEP6: Compute difference of $X_i^{(n-1)}$ and $M_i^{(n-1)}$, If |Xi(n-1) - Mi(n-1)| <TD then go to step 7.

STEP8: $X_i^{(n)} = M_i^{(n-1)}$ N iteration is done and stopped.

STEP7: $X_i^{(n)} = X_i^{(n-1)}$ N iteration is done and stopped.

STEP9: Noise filtering of $X_i^{(n)}$, generate the gray scale image as $\{\{Y_i^{(0)}\}, \{Y_i^{(1)}\}, \ldots\ldots \{Y_i^{(n)}\} \ldots.\}$ and binary image as $\{\{g_i^{(0)}\}, \{g_i^{(1)}\}, \ldots\ldots \{g_i^{(n)}\} \ldots.\}$

STEP10: The $g_i^{(n)}=0$ is noise free, , $g_i^{(n)}=1$ is noisy.

STEP11: For $Y_i^{(n-1)}$ median value 3x3 window $m_i^{(n-1)} = Med\ Y_j^{(n-1)}$

STEP 12: If Gi(n-1) = 1then go to step 14.

STEP 13: Yi(n) =Mi(n-1) N iteration is done and stopped.

STEP 14: Yi(n) =Yi(n-1) N iteration is done and stopped.

STEP 15: Denoised output image.

STEP 16: Calculate the MSE and PSNR value

VI. DECISION BASED ALGORITHM

Decision Based Algorithm [25], [26] here the median value itself can be noisy, especially in the case of high noise density. It is in this case, the pixel value is replaced by the mean of the neighborhood processed pixels. In the 3×3 window above, indicates already processed pixel values, C indicates the current pixel being processed indicates the pixels yet to be processed. If the median value of the above window itself is noisy, then, the current pixel value will be replaced by the mean of the neighborhood processed pixels, that is, the mean. The values of the pixels will not be taken into account since they represent unprocessed pixels. Take the 3×3 matrix of pixels from the padded matrix P. Calculate maximum pixel in the window Wmax. Calculate minimum pixel in the window Wmin. Calculate median in the window. Calculate C=W (2, 2). Check the condition if Wmin<C && C< Wmax and

Wmin<M && M< Wmax and C=W (2, 2) replace with median value else with mean value. Repeat for all possible 3×3 matrix and replace all pixel with the median value. Thus the denoised output image is obtained.

6.1 Algorithm for Decision Based Algorithm

STEP 1: Read the noisy image I.

STEP 2: Convert the color image to gray scale image G.

STEP 3: Pad the G with zeros at the boundaries to form padded matrix P.

STEP 4: Take the 3×3 matrix of pixels from the padded matrix P.

STEP 5: Calculate maximum pixel in the window Wmax.

STEP 6: Calculate minimum pixel in the window Wmin.

STEP 7: Calculate median in the window M.

STEP 8: Calculate C=W (2, 2)

STEP 9: Check the condition if Wmin<C && C< Wmax and Wmin<M && M< Wmax and C=W (2, 2) replace With retain the same pixel value, median value else with mean value.

STEP 10: Repeat for all possible 3×3 matrix and replace all pixel with the median value.

STEP 11: Denoised output image.

STEP 12: Calculate the MSE and PSNR value.

VII. VECTOR MEDIAN FILTER

The vector median filter (VMF) is a nonlinear filter [16], [17], [18]. The VMF is a well-researched and widely used due to extensive modified that can perform in conjunction with it to avoid the damage to the noise free pixel. In the vector median filter the noisy image is taken and the 3×3 window is considered for the complete image. Every pixel in the matrix is considered to be checked for the conditions VMF = W(i) where $1< i \leq 9$ in the window. $\|VMF - W\| \leq \|W_i - W\|$ for $1< i \leq 9$. If this condition satisfies then we replace with the obtained value. The complete image follows the same process there by the impulse noise and the speckle noise is removed.

7.1 Algorithm For Vector Median Filter

STEP 1: Read the noisy image I.

STEP 2: Convert the color image to gray scale image G.

STEP 3: Pad G matrix with zeros at the boundaries to get matrix P

STEP 4: Taking 3×3 matrix of pixel from matrix P.

STEP 5: Considering every pixel as VMF, VMF=W(i).

STEP 6: If $\|VMF - W\| \leq \|W_i - W\|$ then B(i,j)=VMF.

STEP 7: Repeat step 6 for the entire image.

STEP 8: Display the denoised output image.

STEP 9: Calculate the MSE and PSNR value.

VIII. COMPONENT MEDIAN FILTER

The Component Median Filter [19] defined on the statistical median concept. The operation is similar to the median filter but here the separately the median values are replaced for major colors like Red, Green and Blue. Thus by this method we get the noise removed image for color images. This filtering method is simple in construction and it retains the image details for the three colors. This type of filtering takes place for mainly used to remove Salt and Pepper noise.

8.1 Algorithm for Component Median Filter

Step 1: Read the noisy image I.

Step 2: If the noisy image is color, separate each plane using MATLAB commands. Each scalar component is treated independently.

Step 3: Pad the G with zeros at the boundaries to form padded matrix P.

Step 4: Take the 3×3 matrix of pixels from the padded matrix P.

Step 5: Then sort the pixel values within the mask in ascending order.

Step 6: For each component of each point under the mask a single median component is determined.

Step 7: These components are then combined to form a new pixel.

Step 8: Obtain the output image.

Step 9: calculate the MSE, PSNR and MSSIM.

IX. MEAN FILTER

The mean filter technique is a widely used for removing noise it effectively removes the noise while blurs the image details [10]. The mean filtering method is a linear filtering type the mean value in the window will be replaced there by the noise with high values will be removed.

9.1 Algorithm for Mean Filter

STEP 1: Read the noisy image I.

STEP 2: Convert the color image to gray scale image G.

STEP 3: Pad G matrix with zeros at the boundaries to get matrix P

STEP 4: Taking 3×3 matrix of pixel from matrix P.

STEP 5: Calculating the mean value for the window and replace to matrix B.

STEP 6: Repeat step 5 for the entire image.

STEP 7: Display the denoised output image.

STEP 8: Calculate the MSE and PSNR value.

X. WIENER FILTER

Wiener filter [35], [36] is a filter used to produce an estimate of a desired or target random process by linear time-invariant filtering an observed noisy process, assuming known stationary signal and noise spectra, and additive noise. The Wiener filter minimizes the mean square error between the estimated random process and the desired process .Wiener filters are characterized as the following Assumption like signal and noise are stationary linear stochastic processes with known spectral characteristics or known autocorrelation and cross correlation Requirement are the filter must be physically realizable/ causal.

10.1 Algorithm for Wiener Filter

STEP 1: Read the noisy image I.

STEP 2: Convert the color image to gray scale image G.

STEP 3: Apply wiener filtering to the image G.

STEP 4: Denoised output image.

STEP 5: Calculate the MSE, PSNR and MSSIM value.

XI. WAVELET BASED DENOISING

The Discrete Wavelet Transform (DWT) [28-31] based image denoising has the following three steps. The noisy image is considered as the input image and the two level of decomposition takes place after that the soft thresholding [4] is applied also the wavelet coefficients are used. The reconstruction is obtained by Inverse Discrete Wavelet Transform (IDWT). The Wavelet coefficients used are Haar, Daubechies, Symlet, Coiflet and Biorthogonal. Using the Wavelet based noise removal the noise is effectively removed.

11.1 Algorithm for Wavelet Based Denoising

STEP 1: Read the noisy image I.

STEP 2: Convert the color image to gray scale image G.

STEP 3: Perform multistage decomposition of the image G by noise using wavelet transform.

STEP 4: Apply soft thresholding to the noisy coefficients.

STEP 5: Invert the multistage decomposition to reconstruct the denoised image.

STEP 6: median filtering is applied for the reconstructed image.

STEP 11: Repeat for other wavelet coefficients.

STEP 12: Display the denoised output image.

STEP 13: Calculate the MSE, PSNR and MSSIM value.

XII. EXPERIMENTAL RESULTS & DISCUSSION

The experiment carried out in the project is to removal of the different types of the noises. The different noises considered in the project are applied to the various filtering techniques at various densities like 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80%, here noise are considered separately. The experiment shows the comparison of performance of the linear filtering method, nonlinear filtering method and the transform technique to remove the noise in the images which is used in the real application in the field of medical images. The Performance parameters like MSE, PSNR and MSSIM are calculated and tabulated for the tested images.

12.1 Results for Microarray Image

The microarray image with Dimension 512×512 of the format JPEG (Joint Picture Expert Group) is taken as the original image which is in color are converted to gray scale for further filtering analysis

12.1.1 Result for Filtering of Salt and Pepper Noise in Microarray Image

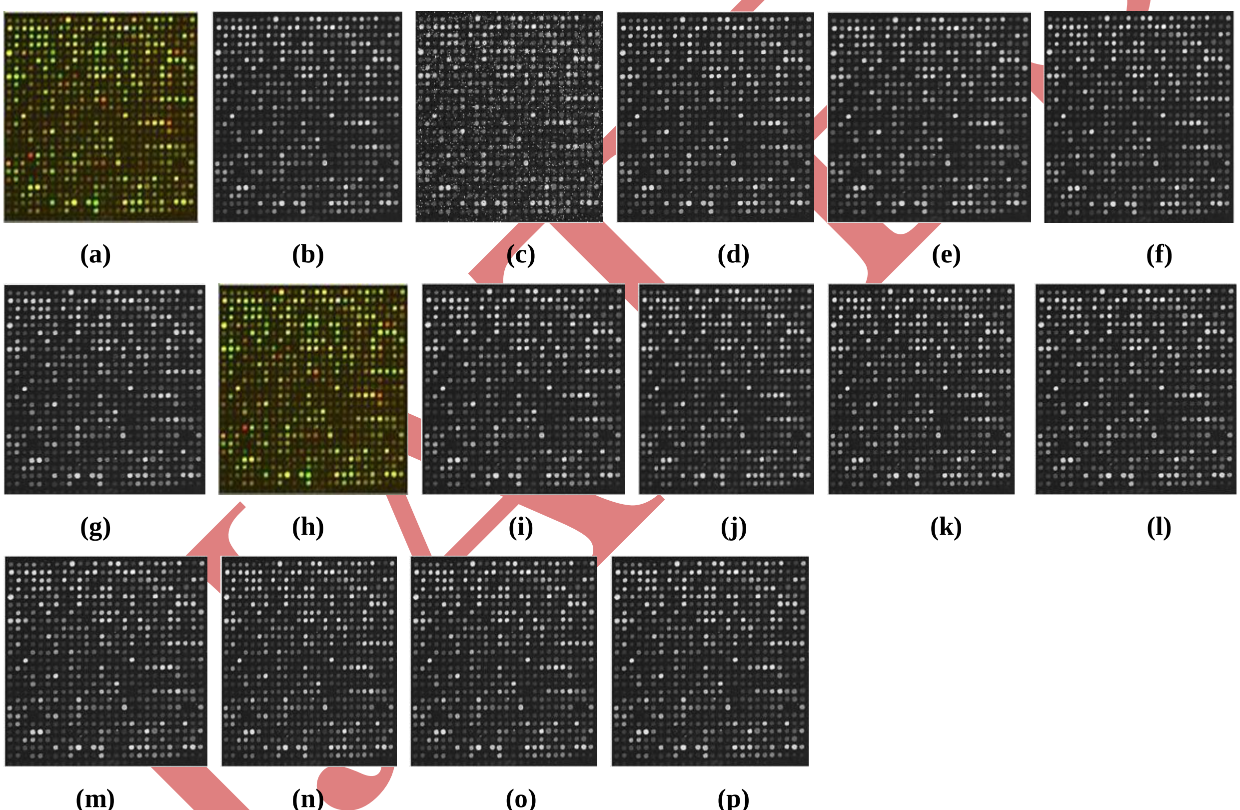


Fig12.1: a)Original image is Microarray image in color b) Original image converted to gray scale image c) Microarray image corrupted with 10% salt and pepper noise d) Noise removed by standard median filter e) Noise removed by SMF f) Noise removed by PSMF g) Noise removed by VMF h) Noise removed by CMF i) Noise removed by DBA j) Noise removed by Mean filter k) Noise removed by wiener l)Noise removed by Wavelet thresholding using Haar coefficient m) Noise removed by DB4 n) Noise removed by Sym4 o)Noise removed by coif4 p)Noise removed by bior3.3

Table12.1: MSE for Different Density of Salt and Pepper Noise in Microarray Image

Filter	Salt and Pepper Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	32.975	34.905	37.200	40.727	44.111	52.964	61.274	75.490	93.521
SMF	**11.013**	**11.840**	**14.158**	**17.926**	**21.550**	**26.228**	**29.004**	**31.023**	**29.949**
PSMF	12.305	20.157	31.235	38.772	43.112	50.694	57.584	69.213	86.958
VMF	33.128	34.950	36.434	39.671	44.570	52.299	61.444	76.734	89.718
CMF	37.534	42.142	36.548	40.604	70.089	76.104	78.820	77.489	72.129
DBA	11.006	11.846	14.216	18.097	22.279	28.163	32.779	37.694	40.669
Mean	39.407	39.870	37.801	35.357	31.800	29.269	26.196	24.585	22.939
WF	36.239	39.198	37.789	35.617	31.930	29.583	26.441	24.737	23.129
Wavelet based Denoising using coefficients									
Haar	48.577	45.431	37.843	32.339	27.646	25.604	22.719	21.269	19.946
DB4	46.356	43.450	35.356	29.936	25.561	23.933	21.612	20.126	19.307
Coif4	45.246	42.800	34.156	28.468	24.589	23.072	21.063	19.648	19.034
Sym4	46.701	44.272	35.734	29.869	25.735	23.813	21.650	20.179	19.314
Bior3.3	49.712	50.169	41.937	34.671	29.025	26.490	23.909	21.754	19.314

The table 12.1 the Switched Median Filter gives less value of MSE which means that the error is less for this type of filter. Similar to the SMF the Decision Based Algorithm performs better.

Table12.2: PSNR for Different Density of Salt and Pepper Noise in Microarray Image

Filter	Salt and Pepper Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	32.948	32.701	32.425	32.053	31.685	30.890	30.258	29.351	28.421
SMF	**37.711**	**37.397**	**36.620**	**35.595**	**34.796**	**33.943**	**33.506**	**33.213**	**33.366**
PSMF	37.229	35.086	33.184	32.245	31.784	31.081	30.527	29.728	28.737
VMF	32.928	32.696	32.515	32.731	31.640	30.045	30.246	29.280	28.602
CMF	32.386	31.835	30.925	30.201	29.674	29.316	29.164	29.238	29.546
DBA	37.714	37.394	36.602	35.554	34.651	33.634	32.974	32.368	32.038
Mean	32.175	32.124	32.355	32.646	33.106	33.466	33.948	34.224	34.524
WF	32.539	32.198	32.357	32.614	33.088	33.420	33.907	34.197	34.489
Wavelet based Denoising using coefficients as:									
Haar	31.266	31.557	32.350	33.033	33.714	34.047	34.566	34.853	35.132
DB4	31.469	31.750	32.646	33.368	34.054	34.304	34.783	35.093	35.273
Coif4	31.575	31.816	32.796	33.857	34.223	34.499	34.895	35.197	35.335

Sym4	31.437	31.669	32.599	33.378	34.025	34.362	34.776	35.081	35.271
Bior3.3	31.166	31.126	31.904	32.731	33.503	33.899	34.345	34.755	35.012

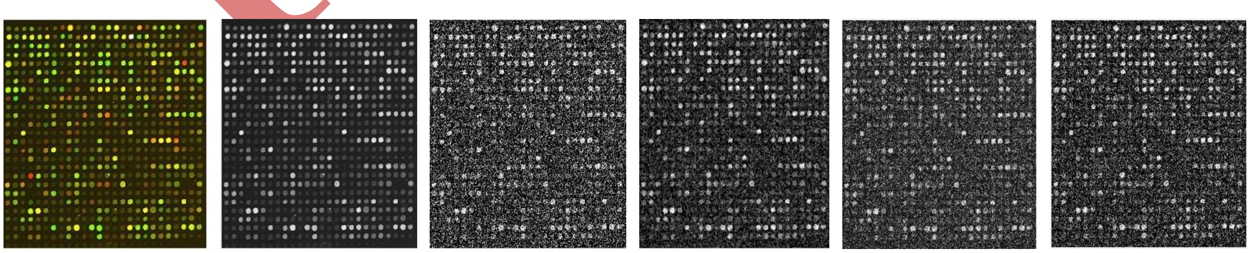
The table 12.2 the Switched Median Filter, Progressive Switched Median Filter, Decision Based Algorithm performs better.

Table12.3: MSSIM for Different Density of Salt and Pepper Noise in Microarray Image

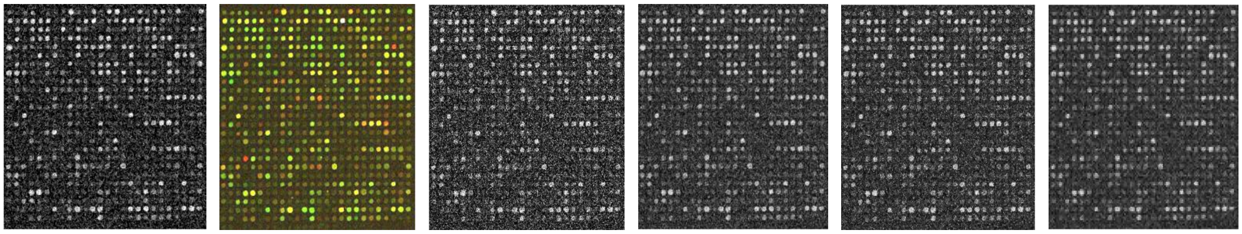
Filter	**Salt and Pepper Noise**								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	0.6248	0.6265	0.6392	0.6328	0.5953	0.5174	0.4053	0.2811	0.1746
SMF	**0.8809**	**0.8899**	**0.8897**	**0.8594**	**0.7966**	**0.7020**	**0.5737**	**0.4357**	**0.3170**
PSMF	0.8767	0.7932	0.7056	0.6497	0.6115	0.5545	0.4633	0.3499	0.2262
VMF	0.6244	0.6279	0.6414	0.4473	0.5967	0.5108	0.4020	0.2709	0.1730
CMF	0.6110	0.6140	0.6223	0.6180	0.5831	0.5070	0.3886	0.2870	0.2181
DBA	0.8809	0.8899	0.8894	0.8571	0.7909	0.6877	0.5514	0.4038	0.2811
Mean	0.6073	0.5664	0.4800	0.4137	0.3619	0.3263	0.2969	0.2733	0.2565
WF	0.6238	0.5626	0.4662	0.4077	0.3492	0.3166	0.2888	0.2659	0.2518
Wavelet based Denoising using coefficients as:									
Haar	0.5079	0.4976	0.4139	0.3624	0.3149	0.2926	0.2702	0.2466	0.2323
DB4	0.6246	0.6055	0.5206	0.4538	0.4162	0.3787	0.3534	0.3224	0.3080
Coif4	0.6470	0.6225	0.5414	0.4759	0.43331	0.3922	0.3632	0.3288	0.3117
Sym4	0.6144	0.5952	0.5217	0.4562	0.4199	0.3839	0.3559	0.3256	0.3081
Bior3.3	0.6456	0.6079	0.5143	0.4473	0.4089	0.3773	0.3481	0.3238	0.3030

The table 12.3 the Switched Median Filter, Progressive Switched Median Filter, Decision Based Algorithm performs better for there are near to 1 which means that the image similarity to that of the original image is closer.

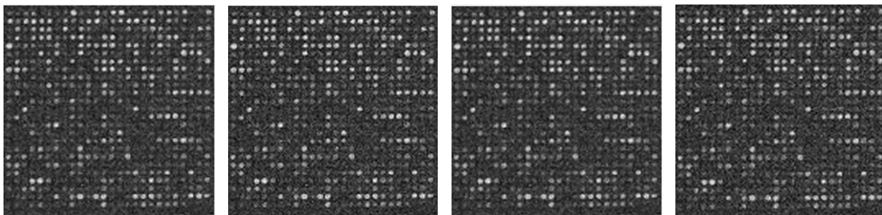
12.1.2 Result for Filtering of Gaussian Noise in Microarray Image



(a) (b) (c) (d) (e) (f)



(g) (h) (i) (j) (k) (l)



(m) (n) (o) (p)

Fig12.2: a)Original image Microarray image b) Original image converted to gray scale image c) Microarray image corrupted with 10% Gaussian noise d) Noise removed by standard median filter e) Noise removed by SMF f) Noise removed by PSMF g) Noise removed by VMF h) Noise removed by CMF i) Noise removed by DBA j) Noise removed by Mean filter k) Noise removed by wiener l)Noise removed by Wavelet thresholding using Haar coefficient m) Noise removed by DB4 n) Noise removed by Sym4 o)Noise removed by coif4 p)Noise removed by bior3.

Table12.4: MSE for Different Density of Gaussian Noise in Microarray Image

Filter	**Gaussian Noise**								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	91.102	100.39	105.50	110.86	112.41	114.51	115.66	116.29	114.46
SMF	79.118	73.403	63.951	59.156	55.180	53.837	51.973	50.266	46.924
PSMF	109.40	113.37	111.87	113.07	112.86	114.12	114.73	114.98	112.48
VMF	88.394	97.332	108.25	109.89	114.39	112.71	115.94	116.77	118.70
CMF	79.920	79.633	78.842	77.924	76.216	74.399	71.313	65.357	45.902
DBA	79.705	75.475	67.976	65.262	61.656	60.883	59.141	58.044	54.856
Mean	45.258	39.762	33.394	30.428	28.977	28.094	27.524	26.339	25.342
WF	45.358	41.011	34.698	31.409	29.832	28.796	27.920	26.991	25.751
Wavelet based Denoising using coefficients as:									
Haar	46.285	38.754	31.704	28.194	26.277	25.442	24.913	24.230	22.578
DB4	45.599	36.905	29.471	25.732	24.275	23.600	23.227	21.833	21.055
Coif4	**43.740**	**34.985**	**27.895**	**24.718**	**23.321**	**22.796**	**22.415**	**21.181**	**20.381**
Sym4	45.057	36.759	29.217	25.598	24.260	23.542	23.137	21.821	21.336
Bior 3.3	47.728	39.257	32.340	29.221	27.041	26.171	24.893	23.993	23.116

The table 12.4 the wavelet based denoising using the coefficient coiflet of order 4 gives less MSE value.

Table12.5: PSNR for Different Density of Gaussian Noise in Microarray Image

Filter	Gaussian Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	28.539	28.113	27.898	27.682	27.622	27.542	27.498	27.475	27.543
SMF	29.148	29.473	30.072	30.410	30.712	30.820	30.973	31.118	31.416
PSMF	27.740	27.585	27.643	27.597	27.605	27.556	27.533	27.524	27.619
VMF	28.666	28.230	27.786	27.721	27.546	27.610	27.488	27.457	27.386
CMF	29.104	29.119	29.163	29.214	29.310	29.415	29.599	29.977	31.512
DBA	29.115	29.352	29.807	29.984	30.231	30.285	30.411	30.493	30.738
Mean	31.573	32.136	32.894	33.298	33.510	33.644	33.733	33.941	34.042
WF	31.564	32.001	32.727	33.160	33.383	33.537	33.671	33.818	34.022
Wavelet based Denoising using coefficients as:									
Haar	31.476	32.247	33.119	33.629	33.934	34.075	34.166	34.287	34.593
DB4	31.541	32.459	33.436	34.026	34.279	34.401	34.471	34.739	34.897
Coif4	**31.722**	**32.691**	**33.675**	**34.200**	**34.453**	**34.552**	**34.609**	**34.871**	**35.608**
Sym4	31.593	32.477	33.474	34.048	34.281	34.412	34.487	34.742	34.839
Bior 3.3	31.343	32.191	33.033	33.473	33.810	33.952	34.167	34.329	34.491

The table 12.5 the wavelet based denoising using the coefficient coiflet of order 4 gives high PSNR value which performs better than other filtering technique.

Table12.6: MSSIM for Different Density of Gaussian Noise in Microarray Image

Filter	Gaussian Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	0.4826	0.3957	0.3191	0.2788	0.2527	0.2326	0.2219	0.2087	0.1990
SMF	0.3766	0.3108	0.2538	0.2341	0.2216	0.2144	0.2110	0.2067	0.2036
PSMF	0.2681	0.2603	0.2633	0.2526	0.2416	0.2298	0.2224	0.2116	0.2048
VMF	0.4843	0.3442	0.3185	0.2778	0.2557	0.2349	0.2205	0.2084	0.1994
CMF	**0.7279**	**0.6771**	**0.5667**	**0.4754**	**0.3997**	**0.3324**	**0.2692**	**0.2066**	**0.1322**
DBA	0.3732	0.3042	0.2450	0.2227	0.2039	0.2013	0.1977	0.1929	0.1890
Mean	0.5877	0.4971	0.4148	0.3725	0.3467	0.3278	0.3183	0.3108	0.3010
WF	0.5883	0.4792	0.3935	0.3537	0.3312	0.3119	0.3039	0.2978	0.2883
Wavelet based Denoising using coefficients as:									
Haar	0.4107	0.3780	0.3422	0.3201	0.3060	0.2920	0.2828	0.2783	0.2712

DB4	0.5232	0.4913	0.4444	0.4219	0.3962	0.3789	0.3685	0.3621	0.3565
Coif4	0.5625	0.5229	0.4658	0.4397	0.4101	0.3933	0.3798	0.3729	0.3651
Sym4	0.5272	0.4948	0.4480	0.4239	0.4002	0.3846	0.3712	0.3651	0.3584
Bior3.3	0.5442	0.4990	0.4445	0.4136	0.3911	0.3763	0.3663	0.3583	0.3493

The table 12.6 the Component Median Filter performs better.

12.1.2 Result for Filtering of Speckle Noise

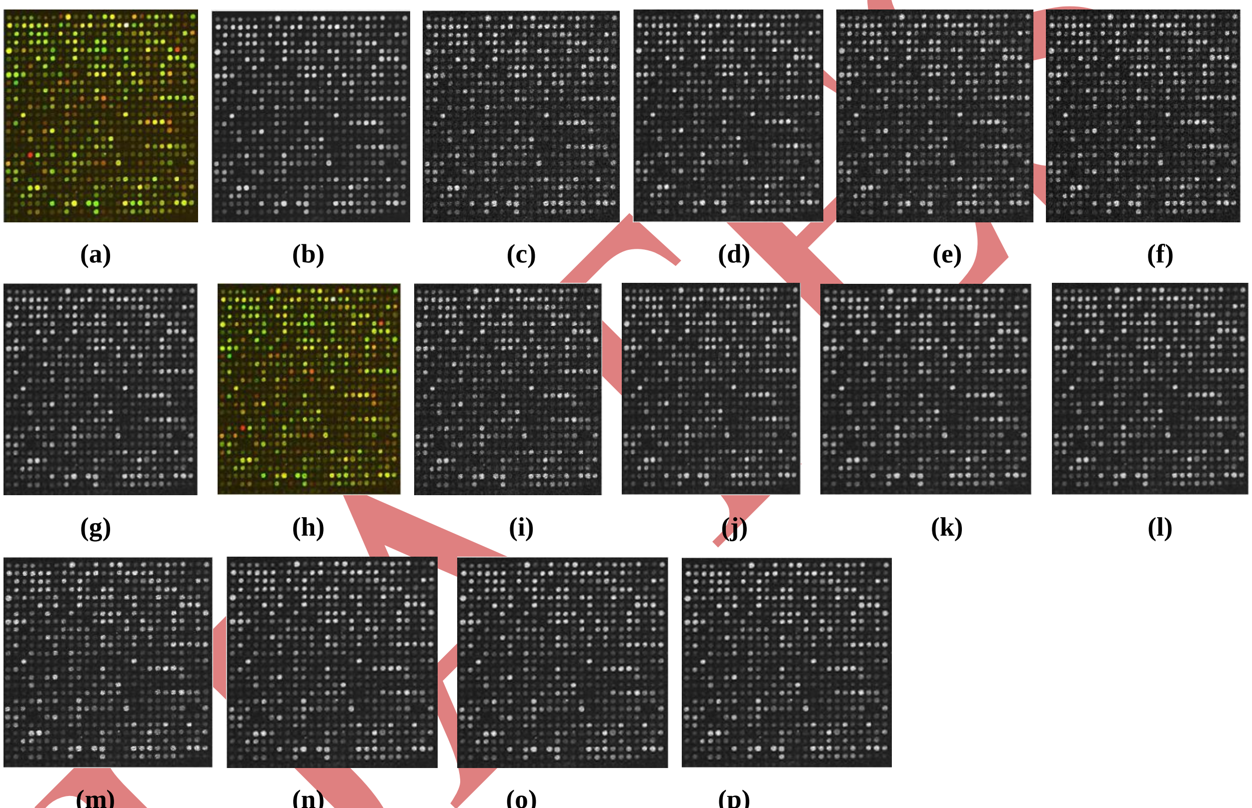


Fig 12.3: a)Original image Microarray image b) Original image converted to gray scale image c) Microarray image corrupted with 10% Speckle noise d) Noise removed by standard median filter e) Noise removed by SMF f) Noise removed by PSMF g) Noise removed by VMF h) Noise removed by CMF i) Noise removed by DBA j) Noise removed by Mean filter k) Noise removed by wiener l)Noise removed by Wavelet thresholding using Haar coefficient m) Noise removed by DB4 n) Noise removed by Sym4 o)Noise removed by coif4 p)Noise removed by bior3.3

Table12.7: MSE for Different Density of Speckle Noise in Microarray Image

Filter	Speckle Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	51.760	59.830	68.920	76.220	81.547	85.728	87.948	91.648	93.700
SMF	45.967	59.861	72.946	82.133	88.198	90.410	90.503	91.393	91.724
PSMF	45.300	65.645	84.936	94.476	100.30	104.28	106.22	109.43	111.05
VMF	51.728	60.119	68.565	77.349	82.490	84.066	88.718	63.530	93.511
CMF	51.400	59.404	68.157	73.108	76.338	78.447	80.588	81.906	82.812
DBA	45.979	59.886	72.938	82.097	88.164	90.351	90.455	91.266	91.516
Mean	42.053	44.802	48.461	53.475	55.604	57.987	57.285	58.320	57.748
WF	**35.298**	**39.428**	**43.863**	**48.824**	**51.756**	**54.086**	**54.125**	**55.383**	**55.031**
Wavelet based Denoising using coefficients as:									
Haar	54.140	55.559	56.761	59.090	59.513	60.083	59.294	58.877	57.977
DB4	54.347	56.582	58.373	61.760	62.262	61.866	61.279	60.690	59.572
Coif4	53.068	55.829	57.995	61.158	61.675	61.623	61.029	60.133	59.085
Sym4	53.669	56.031	57.939	61.075	61.721	61.312	60.867	60.337	59.121
Bior3.3	51.839	54.594	57.633	61.047	62.749	64.200	63.037	63.530	62.249

From the table 13.7 the Weiner Filter gives less MSE value.

Table12.8: PSNR for Different Density of Speckle Noise in Microarray Image

Filter	Speckle Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	30.990	30.361	29.747	29.310	29.016	28.799	28.688	28.509	28.413
SMF	31.506	30.359	29.500	28.985	28.676	28.568	28.564	28.521	28.506
PSMF	31.569	29.958	28.839	28.377	28.117	27.948	27.868	27.739	27.675
VMF	30.993	30.340	29.755	29.246	28.966	28.884	28.650	30.101	28.422
CMF	31.021	30.392	29.795	29.491	29.303	29.185	29.068	28.997	28.949
DBA	31.505	30.357	29.501	28.987	28.677	28.571	28.566	28.527	28.515
Mean	31.892	31.617	31.276	30.849	30.679	30.497	30.550	30.472	30.515
WF	**32.653**	**32.172**	**31.709**	**31.244**	**30.991**	**30.799**	**30.796**	**30.697**	**30.724**
Wavelet based Denoising using coefficients as:									
Haar	30.795	30.683	30.590	30.415	30.384	30.343	30.400	30.431	30.498
DB4	30.779	30.604	30.468	30.223	30.188	30.216	30.257	30.299	30.380
Coif4	30.882	30.662	30.496	30.266	30.229	30.233	30.275	30.339	30.416
Sym4	30.833	30.646	30.501	30.272	30.226	30.255	30.286	30.325	30.413
Bior3.3	30.984	30.759	30.524	30.274	30.154	30.055	30.134	30.101	30.183

From the table 12.8 The Weiner Filter gives high PSNR value which performs better as filtering technique.

Table12.9: MSSIM for Different Density of Speckle Noise in Microarray Image

Filter	Speckle Noise								
	5%	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**
MF	0.6923	0.6954	0.6641	0.6330	0.6036	0.5781	0.5568	0.5320	0.5142
SMF	**0.8066**	**0.7128**	**0.5921**	**0.5162**	**0.4641**	**0.4357**	**0.4146**	**0.3973**	**0.3886**
PSMF	0.7146	0.5891	0.4532	0.3864	0.3441	0.3214	0.3055	0.2905	0.2836
VMF	0.6909	0.6920	0.6630	0.6322	0.6016	0.5798	0.5488	0.5736	0.5145
CMF	0.6657	0.6828	0.6862	0.6781	0.6667	0.6474	0.6330	0.6204	0.6088
DBA	0.8065	0.7127	0.5920	0.5161	0.4637	0.4353	0.4142	0.3969	0.3876
Mean	0.6820	0.7047	0.7199	0.7115	0.7018	0.6878	0.6805	0.6654	0.6558
WF	0.7154	0.7310	0.7365	0.7240	0.7054	0.6894	0.6768	0.6603	0.6479
Wavelet based Denoising using coefficients as:									
Haar	0.4440	0.4406	0.4388	0.4302	0.4312	0.4242	0.4257	0.4199	0.4259
DB4	0.5670	0.5643	0.5530	0.5465	0.5476	0.5444	0.5436	0.5350	0.5404
Coif4	0.5936	0.5949	0.5884	0.5855	0.5884	0.5822	0.5813	0.5744	0.5803
Sym4	0.5581	0.5578	0.5513	0.5474	0.5521	0.5467	0.5460	0.5390	0.5458
Bior3.3	0.5873	0.5936	0.5893	0.5838	0.5834	0.5790	0.5809	0.5736	0.5707

From the table 12.6 the Switched Median Filter performs better for there are near to 1 which means that the image similarity to that of the original image is closer.

XIII. CONCLUSION

The scope of the paper is to retrieve the image after Denoising. The implementation was carried out using Matlab 2011b. The Noise that was considered in the project is Salt and Pepper, Gaussian and Speckle noise. The different filtering techniques were implemented to evaluate the performance of their noise removal in real application images.

The image quality analysis parameters used in the project are MSE PSNR and MSSIM values. The performance evaluation is done on the criteria that MSE value should be low and PSNR value should be high then quality of image retrieving high, in the case of the gray scale images the value for PSNR ranges from 30 to 50 for good performance of the image. The structural similarity of the image tested obtained after denoising which was compared with the original image without noise. The MSSIM parameter for good quality of the image value should be nearer to 1.

The result analysis shows that to remove the Salt and Pepper noise, the Decision based algorithm and Switched Median Filter yields better performance. Similarly for Gaussian noise and Speckle noise the Wavelet Transform obtained better removal noise. The MSSIM value is high for less noise density, whereas for high density of the noises the perceptual image quality performance is poor. This paper achieves in evaluating to find the better noise removal technique in real time applications.

13.1 Future Enhancement

This paper can further extended by implementing using different filters and it can be implemented in hardware simulation using FPGA. Using the hardware implementation in the future may give a perfect reconstruction using Wavelet Transform. Further implementation can be carried out for Edge detection, Segmentation, or Pattern Recognition were for all these methods denoising is the preprocessing method. The filtering techniques can be applied to the real application medical images.

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