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Wavelet Transform Based Microarray Image De-noising

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***Abstract*— Accuracy of microarray gene expression based cancer classification depends on microarray image processing techniques. Image de-noising is one of the crucial step of the microarray image processing. Better the quality of microarray image, more accurate will be the result of cancer classification. In this paper, we have implemented Median filter and wavelet transform based filters with various thresholding techniques, to de-noise the microarray image. The performance of filters is compared using mean square error and peak signal to noise ratio.**

***Keywords*— Messenger ribo-nucleic acid, complementary De-oxyribo nucleic acid, mean square error, peak signal to noise ratio.**

I. INTRODUCTION

The Microarray technology plays a vital role in the field of bioinformatics by allowing us to monitor the expression levels of thousands of genes at once [1], [2]. It caters wide range of applications from cancer diagnosis to human identification[3].Microarrays will be a normal diagnostic method in future much like today's blood test[1]. Microarray experiment, image processing and data analysis are the major steps of Microarray technology [2].

In microarray experiment first the mRNA is mined from the normal and the cancerous cell. Then mRNA is transformed into cDNA and characterized with dissimilar dyes (red, green).Further, cDNA is hybridized onto the microarray slide. Following this, the microarray slide is then exposed to the laser at suitable wavelength to identify red and green dyes. The resultant microarray image is stored can be used for further processing. The microarray image contains of thousands of spots. Each spot includes multiple copies of the same DNA sequence which, uniquely signifies a gene [2].

In practical microarray image, the spots are not round in nature, not aligned accurately, the background intensity is disturbing the spot intensity. Microarray image is degraded due to several types of noises. Due to these reasons, microarray image requires further processing, before cancer sub-classification [4]. The steps in microarray image processing are de-noising, gridding, segmentation and quantification.

During the course of microarray experiment, microarray image is degraded with several noises like sample preparation noise, scanning noise and hybridization noise. Sample preparation noise is introduced in the process of transforming mRNA-cDNA. The mRNA molecules are intensified by factor A. The factor A varies from sample to sample.

Another reason for sample preparation noise is the inherent chemical procedure involved in sample preparation. During scanning, noise is introduced due to photon noise, electron noise in photo multiplier tube, laser light leakage, reflection and quantization noise. Hybridization noise arises from fluctuation in target molecules binding and cross hybridization [1], [5], [6]. The noise can be reduced either by precisely adjusting the fabrication machine, fluorescent dyes, normalizing the experimental conditions or by designing appropriate filter.

Improvement of the experimental conditions does not remove the noise completely. The enhanced way to decrease the noise is by designing appropriate filter. The microarray image can be de-noised using the filters in the pixel domain (filters) [7], [8], [9] or in the transform domain (PCA, Wavelets etc.)[10], [11], [12].

We propose to de-noise the microarray image using Median filter and wavelet transform based filters using various thresholding techniques. In this paper, section II explains the methods, section III shows the steps in the implementation and result analysis is described in section IV.

II. METHODS

A. Median filter

Median filter is nonlinear pixel domain filter. Here, the central pixel is replaced by median of gray levels in neighbourhood of central pixel. Median filter makes pixels with dissimilar gray levels to be like their neighbours. This filter works very well for salt and pepper noise.

B. Wavelet Transform based filter

Wavelet analysis has a potential of revealing features of data that other signal analysis techniques fail to do like trends, breakdown points, discontinuities in higher derivatives, and self-similarity. The custom made filters of wavelet transform work well in an image noise reduction. In the case of wavelet transform based filters first, the image is decomposed into approximation and detailed coefficients. The approximation coefficients represent the low frequency part of the image while detailed coefficients represent the high frequency part of the signal. The low frequency part is normally an information signal and does not usually contain noise. The detail coefficients are the high frequency coefficients which includes information about edges and noise. Noise is present in high frequency components and edges are present in the frequency components higher than noise frequency components. In order to remove noise and preserve edges it is necessary to select the threshold correctly. Therefore, the threshold can be chosen and wavelet coefficients can be thresholded using hard threshold.

Finally, the image is reconstructed using the original approximation coefficients and the altered detail coefficients [13].

The threshold can be selected using different ways as shown below:

1. Visushrink:

$$th = \sigma\sqrt{2\log n}$$

where,

σ = variance of noise in an image

= median (absolute (detailed coefficient.))/0.6745

n=number of pixels in an image

2. Bayes shrink:

$$th = \frac{\sigma^{\wedge}2}{\sigma x^{\wedge}2}$$

where,

σ = variance of noise in an image

= median (absolute (detailed coefficient.))/0.6745

$$\sigma x = (\max(\sigma y^{\wedge}2 - \sigma^{\wedge}2),0)$$

$$\sigma y^{\wedge}2 = (1/2)\sum(horizontal coefficients)^{\wedge}2$$

3. Normal shrink: It is a level based thresholding method.

$$th = \beta\left(\sigma^{\wedge}2 / \sigma y\right)$$

Where,

$$\beta = \left(\log\left(\frac{jk}{l}\right)\right)^{\wedge}0.5$$

σy =standard deviation of sub band under consideration

jk = length of sub band

l = level of decomposition.

The detail coefficients to be used for an image reconstruction are decided using hard and soft thersholding. In case of hard thresholding the wavelet coefficients less than threshold are made zero and coefficients larger than threshold remain same. The formula for hard threshold is given as [13]

$$coe = w; |w| >= th$$

$$coe = 0; |w| < th$$

where,

coe = detailed wavelet coefficients after thresholding

w = detailed wavelet coefficients before thresholding.

In case of soft thresholding the wavelet coefficients less than threshold are made zero and coefficients larger than threshold are not retained. The formula for soft threshold is given as [13]

$$coe = sign(w)(|w| - th); |w| >= th$$

$$coe = 0; |w| < th$$

The quality of de-noised image is checked by using parameters:

a. MSE: Mean square error: Cumulative error between noisy image and noise image.

$$MSE = \sum_{0<=i<=m, 0<j<n} [(I(i,j) - K(i,j)]^{\wedge}2$$

b. PSNR: Peak signal to noise ratio.

$$PSNR = 10\log\left(\max(I)^{\wedge}2 / mse\right)$$

Where,

I= Original image,

K= De-noised image,

max I= 255 for 8 bit image.

III. IMPLEMENTATION

All The microarray image is generated using Microarray Scan Simulator [14]. The microarray image is as shown in Figure (1).

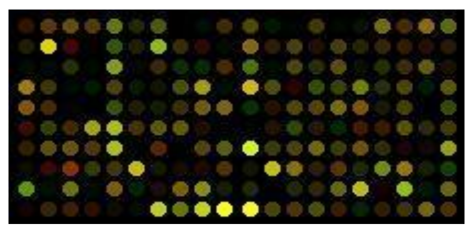

Figure (1). Microarray image.

In order to de-noise the microarray image first the Gaussian white noise with zero mean, known variance and Poisson's noise are added to microarray image. The resultant noisy image is de-noised using Median filter and wavelet transform based technique. For de-noised image mean square error and peak signal to noise ratio.

IV. RESULT

The mean square error and peak signal to noise ratio for different de-noising methods is as shown below

TABLE I
MEDIAN FILTER RESULTS

Sr.no	Mean and variance	Median filter	
		Mse	Psnr
1	0,0.5	41.5635	31.9438
2	0,2.5	42.9435	31.8026
3	0,3.5	44.4479	31.6529
4	0, 5	47.7892	31.3377
5	0,25	166.5944	25.9151
6	0,35	266.9120	23.8673

TABLE II
VISUSHRINK THRESHOLDING RESULT

Sr.no	Mean and variance	Visushrink			
		Hard Thresholding		Soft Thresholding	
		MSE	PSNR	MSE	PSNR
1	0,0.5	36.9526	32.4548	62.7249	30.2864
2	0,2.5	41.8776	31.9110	67.8803	29.9108
3	0,3.5	45.8200	31.5206	71.9939	29.6455
4	0, 5	54.8082	30.7423	81.1672	29.1023
5	0,25	273.024	23.7688	272.291	23.7823
6	0,35	448.583	21.6125	421.735	21.8804

TABLE III
BAYES SHRINK THRESHOLDING RESULT

Sr.no	Mean and variance	Bayes shrink			
		Hard Thresholding		Soft Thresholding	
		MSE	PSNR	MSE	PSNR
1	0,0.5	26.6915	33.8672	41.2523	32.2240
2	0,2.5	32.0815	33.0745	45.4607	31.7384
3	0,3.5	37.4338	32.3989	50.3006	31.2591
4	0, 5	46.6837	31.4411	59.5512	30.4623
5	0,25	443.944	21.6577	406.157	22.0485
6	0,35	806.824	19.0637	717.674	19.5780

TABLE IV
NORMAL SHRINK THRESHOLDING RESULT

Sr.no	Mean and variance	Normal shrink			
		Hard Thresholding		Soft Thresholding	
		MSE	PSNR	MSE	PSNR
1	0,0.5	26.0688	33.9715	39.8600	32.3879
2	0,2.5	31.4003	33.1615	42.7701	32.0483
3	0,3.5	36.1042	32.5559	46.3786	31.6687
4	0, 5	45.3549	31.5653	53.1157	30.9866
5	0,25	380.170	22.3314	276.554	23.7169
6	0,35	666.683	19.8920	463.100	21.4931

V. CONCLUSION

It can be concluded that for lower values of variance of noise, wavelet transform based filter using Normal shrink hard thresholding method works better than other methods. Also, due to the large number of edges in microarray image, filters using hard thresholding works better. With increase in the noise variance, Gaussian noise tends more like salt and pepper noise and as a result Median filter works well than wavelet filters.

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