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Integrating the Concept of Guided Image Filter and Coefficient Thresholding for Image Denoising

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Abstract: - Image acquisition techniques introduce various types of artifacts and noise such as additive white gaussian noise, salt and pepper noise etc, so image denoising is an essential preprocessing step in digital image processing. It is clear from the background study of denoising, conventional methods are not much effective in reducing the noise in the image. In this work, a novel approach which integrates the concept of guided image filter and coefficient thresholding for the removal of different types of noise. Guided image filter is a spatial domain method and coefficient thresholding is a wavelet domain method. Guided image filter has no gradient distortion and has better performance near the edges. Inorder to enhance the output of the guided image filter, wavelet based edge detection is performed. The output obtained by wavelet based edge detection has better visual quality than the one obtained by conventional edge detectors. Also variance of the image has been calculated and smooth and texture regions are separated for coefficient thresholding. Threshold values are calculated and coefficient thresholding is performed. The tool used for this denoising algorithm is MATLAB R2012b. The denoised output obtained by this method has high peak signal to noise ratio (PSNR). By this proposed method, it is possible to get a denoised image which can be used for different applications such as haze removal, feathering etc.

Keywords:- Coefficient thresholding, guided image filter,image denoising, peak signal to noise ratio, wavelet based edge detection.

I. INTRODUCTION

Digital images [7] are very much essential for daily life applications such as satellite television, medical imaging etc. It is also essential for the researches in the area of science and technology such as geographical information and astronomy. During the acquisition of these images, it is affected by different types of noises. Noise may be generated due to imperfect instruments , problems with the data acquisition process ,interference transmission errors and compressions. All of this interference can degrade the data of interest. Hence noise removal is essential in digital imaging applications inorder to recover and enhance the fine details that are hidden in the data. Noise in a digital image has low frequency and high frequency components. High frequency components can be easily removed and the removal of low frequency component is a difficult task as it difficult to distinguish between real and low frequency components.

During the filtering of random noise [2] , two factors are considered. One is how much of the noise granularity has been removed and how well the edges are preserved. Usually noise in digital image is found to be additive in nature with uniform power in the whole bandwidth and with gaussian probability distribution. Such a noise is referred to as additive white gaussian noise. Usually this additive white gaussian noise is suppressed using linear spatial filter such a mean and wiener filter, but low pass filter will not only smooth away the noise but also blur the edges in the images. In the case of high pass filtering, which improves the spatial resolution but will also amplify the noisy background. Wavelet thresholding is one of the most popular denoising method which apply the thresholding shrinkage upon the high frequency component after wavelet decomposition for removing blurring effect at the edges.

This paper is organized as follows: In section II, proposed method is discussed. Section III introduces guided image filter. Section IV describes discrete wavelet transform. Section V explains the wavelet based edge detection method. Section VI explains the separation of smooth and texture areas. Section VII explains the morphological operation used. In section VIII, threshold selection is explained. Section IX explains coefficient thresholding. Section X presents the experimental results and discussion while concluding remarks are given in section XI.

II. PROPOSED METHOD

Fig. 1 represents the proposed method. In this method, the original image is added with additive white gaussian noise, inorder to generate the noisy image. Then the noisy image is passed through a guided image filter (spatial domain method). For enhancing the edges, the guided filter output undergoes wavelet based edge detection. After spatial domain approach, wavelet domain method is performed on the guided filter output. In the wavelet domain method, coefficient thresholding is performed. Inorder to perform coefficient thresholding, the regions of the image is separated as smooth and texture areas, morphological operation is performed, variance of the image is calculated and threshold values are selected for each regions. Here the threshold value is selected on the basis of stain's unbiased risk estimate. Then coefficient thresholding is performed. Finally the guided filter output and the thresholded output combined together to obtain the edge preserved denoised image.

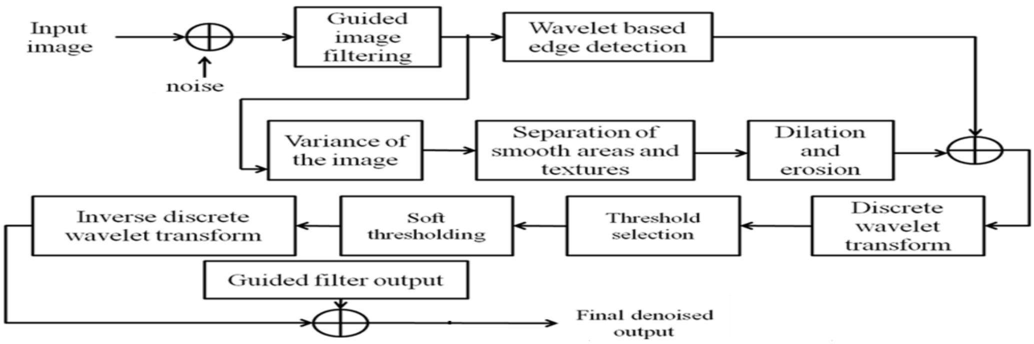


Fig1.Proposed method

III. GUIDED IMAGE FILTER

In the first stage, spatial domain method is performed. So initially, the noisy image under goes guided image filtering. Guided image filter[9] is a spatial filter which generates the filtering output by considering the content of a guidance image. The guidance image may be the input image or any other image. It is an edge preserved non-iterative filter and it has less gradient distortion near the edges. Since it is a non-iterative filter, so it is fast and accurate. It is also independent of the filtering kernel size. Two important parameters of the guided image filter are window radius 'r' and regularization 'ε'. Window radius (r) represents the window radius of the mean filter used in the algorithm of guided image filter. Regularization (ε) is used to provide a balance between data matching and smoothing. The value of ε never be equal to zero.

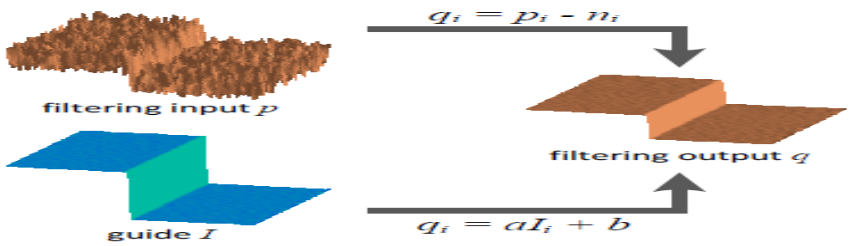


Fig 2. Guided image filtering

Fig 2 represents the guided image filtering. From the figure it is clear that the input image p is the image which we want to filter, it is not smooth. I represent the guide image which is a smooth image. The guided image filter is a linear model between the output image and the guidance image. The filtered output is represented by q, which is a smooth image. So, the output of the guided image filter is given by

$$Q_i = aI_i + b \qquad (1)$$

Where a,b are the linear coefficients.

$$a = \mathrm{Cov}(I,P) \qquad (2)$$

$$b = \mathrm{mean}(p) - a\mathrm{mean}(I) \qquad (3)$$

IV. DISCRETE WAVELET TRANSFORM

In this work, discrete wavelet transform is used for performing the wavelet based edge detection. Also it is used for the selection of threshold values for coefficient thresholding.

Discrete wavelet transform [1,5,17,13] is a spatial frequency decomposition which provides flexible multiresolution analysis of the image. It is calculated by passing the signal through a series of high pass and low pass filter. It deals with two set of function : scaling function (approximation coefficient) and wavelet function (detailed coefficient). High pass filtering gives detailed coefficients. Low pass filtering associated with approximation coefficient.

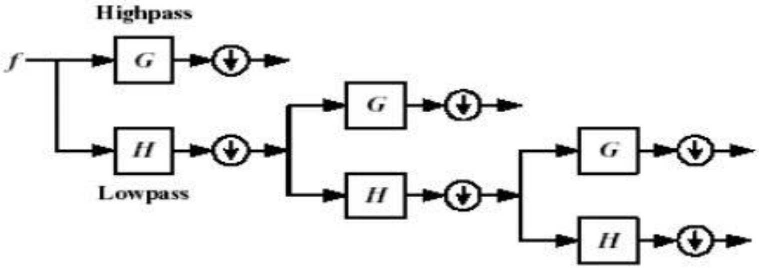


Fig 3.Discrete wavelet transform

Fig 3 represents the process of discrete wavelet transform. Here the original signal is passed through a high pass filter and a low pass filter and down sampling the high pass filter gives the detailed coefficients. After low pass filtering, the signal is down sampled and the down sampled signal is again passed through low pass filter and high pass filter. This process is continued until the desired output is obtained. The reconstruction is the reverse process of decomposition. The approximation and detail coefficient at every level are up sampled and passed through low pass filter and high pass filter and then finally added to get the original signal. So this discrete wavelet transform is used to separate the low frequency and high frequency components.

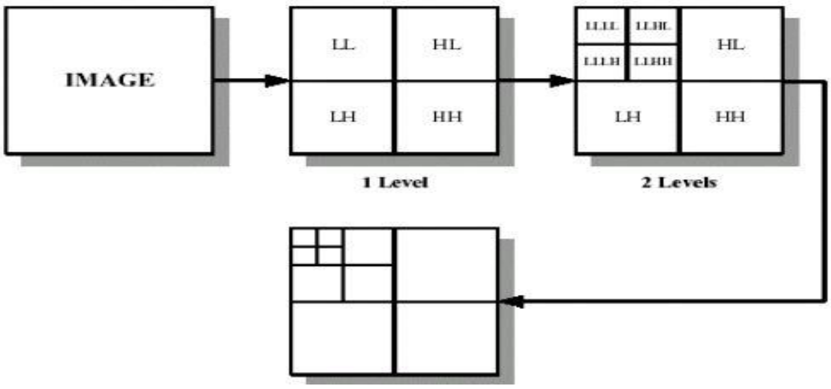


Fig 4.Generation of wavelet coefficients

Fig 4 represents the generation of wavelet coefficients [12]. Here after first level decomposition, four coefficients are generated. First coefficient represents the low frequency component and the remaining three are the high frequency component. As the level increases, the information in the image get reduces.

V. WAVELET BASED EDGE DETECTION

Guided image filter is an edge preserved filter. In order to enhance the edges of the image in this work, wavelet based edge detection [4] is performed. In this method, after wavelet decomposition four coefficients are present. One low frequency component and three high frequency component. Edges are the high frequency components. In order to detect the edges, make the low frequency component equal to zero. Then take the inverse discrete wavelet transform and finally calculate the absolute value. The final output is a edge detected output.

VI. SEPARATION OF SMOOTH AND TEXTURE AREAS

After wavelet based edge detection, coefficient thresholding is performed [2]. Inorder to perform coefficient thresholding, first the smooth and texture areas of the images are separated. For the separation of smooth and texture areas, first the variance of the image is calculated. From the variance image, smooth and texture areas are separated.

Variance of the image is calculated using the equation

$$v[i,j] = \sum_{m,n\,\in c} (f(i,j) - f(m,n))^2 \qquad (4)$$

Where v[i,j] is the variance image, f(i,j) is the original image and f(m,n) represents the mask used. Here a box filter is used as mask of size 3 x3.
The variance image is roughly an estimate of the local variance and in a smooth region contaminated by noise, it should be approximately equal to the noise variance σ^2. Hence the pixel V[i,j] satisfies the following condition are labeled SMOOTH:

$$\frac{1}{(1+\delta)} \leq \frac{v[i,j]}{\sigma^2} \leq (1+\delta) \quad (5)$$

The remaining points are classified as TEXTURE regions. The value of δ is different for different images.

VII. MORPHOLOGICAL OPERATIONS

After the separation of smooth and texture areas, there occur some errors. Sometimes the smooth areas may be wrongly decided as texture areas and vice versa. In order to eliminate these errors, morphological operations are performed on the separated output. First dilation is performed on the separated output. On the dilated output, erosion is performed.

Mathematical Morphology[2,7,14] is a method for quantitative analysis of spatial structures that aims at analyzing shapes and forms of an object. Mathematical morphology is based on set theory. The shapes of objects in a binary image are represented by object membership sets. Objects are connected areas of pixels with value 1, the background pixels have value 0. Binary mathematical morphology is based on two basic operations, defined in terms of a structuring element, a small window that scans the image and alters the pixels in function of its window content: a dilation of set A with structuring element B enlarges the objects, an erosion shrinks objects.

7.1*Structuring element* : Structuring elements determines exactly how the objects will be dilated or eroded. It has both shape and origin. The structural elements are smaller than the processed image. The center pixel of the structuring element is called origin and this identifies which pixel is being processed.

7.2*Dilation* : Dilation allows the object to expand. So by dilation, the number of white pixel in the image get increased. Mathematically, dilation of the image f with structuring element s is given by $f \cup s$.

7.3 *Erosion :* Erosion reduces the size of the object. So by this, the number of black pixel in the image gets reduced. So erosion of the image f by structuring element s is given by $f \cap s$.

VIII. THRESHOLD SELECTION

After morphological operations, the eroded output and the edge detected output combine together to form a single output[2,10,11,15]. On the single output, discrete wavelet transform is performed. After wavelet transformation, four coefficients are generated. In each wavelet coefficient, threshold value is selected based on SURE shrink.

8.1*SURE shrink:* This method is based on Stain's Unbiased Risk Estimator. This method is a combination of universal and SURE threshold. In this method, it specifies a threshold value t_i for each resolution level j in the wavelet transform. This method is also referred to as level dependent threshold. The main objective of SURE shrink is to minimize the mean square error. SURE threshold, t* can be calculated using the equation :

$$t^* = \min(t, \sigma\sqrt{2\log n}) \quad (6)$$

where t is the value that minimizes stain's unbiased risk estimate, σ is the noise variance and n is the size of the image.

IX. COEFFICIENT THRESHOLDING

Wavelet thresholding [2,15,12] is one of the most popular methods used for image denoising. In this, the threshold values are applied on the high frequency component after wavelet decomposition. There are mainly two types of thresholding techniques are used. One is soft thresholding and the other is hard thresholding. In both cases, the coefficients below a particular threshold are set to zero. In hard thresholding, all the coefficients above a particular threshold are remain unchanged. In the case of soft thresholding, the coefficient values above particular threshold are reduced by an amount equal to the threshold value. In the case of image denoising, usually soft thresholding is used. It is because soft thresholding yield more visually pleasing images than hard thresholding. Coefficient thresholding is a type of soft thresholding.

X. RESULTS AND DISCUSSION

Experiments using guided image filter and coefficient thresholding are conducted on a set of images such as cameraman, peppers, coins, moon, pout and medical image. Fig 5 represents the original image. Different images are of different size. So first resize the image to 256 X256. Fig 6 represents the noise image with standard deviation 0.05. Here the noise used is additive white gaussian noise. Fig 7 represents the guided filter output with different window size. Window size is one of the Parameter of guided image filter. As the window size increases, the blurring of the image also increases. For wavelet based edge detected, first discrete wavelet transform is performed on the guided filter output. It is shown in fig 8. First figure represents the approximation coefficient which contains the smooth area of the image. Remaining are the high frequency component which represents the diagonal, horizontal and vertical components. It contains the edges of the image. The output of wavelet based edge dtection is shown in fig 9. Edge detection is performed using conventional edge detetctors. It is given in fig 10. It has the disadvantage of yielding poor visual quality when it combines with bae ckground information.

For the separation of smooth and texture areas, first calculate the variance image. The variance image is shown in fig 11. From the variance image, the smooth and texture regions are separated based on a condition. As the delta value increases, the smooth areas get reduced. In the fig 12 represents the saeparation of smooth and texture area with different δ values. After te separaion of smooth and texture aras, performed there occur some errors. Inorder to remove these errors, morphological operations are performed on the separated image. First dilation is performed on the separated output. On the dilated output, erosion is performed. Morphological output is shown in fig 13. Next the morphological output and the edge detected output are combined to form a single image. It is shown in fig 14.

Next, the thresholded values are selected on the wavelet coefficient. So perform the discete wavelet transform on the added output. It is shown in fig 15. Threshold values are selected for each region using SURE shrink and it is shown in fig 16. With the selected threshold value, coefficient thresholding is performed on each wavelet coefficient and it is shown in fig 17. Then take the inverse discrete wavelet transform. It is shown in fig 18. Finally the thresholded output and the guided filter output are combined to form the final edge preserved denoised output. It is shown in fig 19.

Fig 5. Original image **Fig 6. Noisy image**

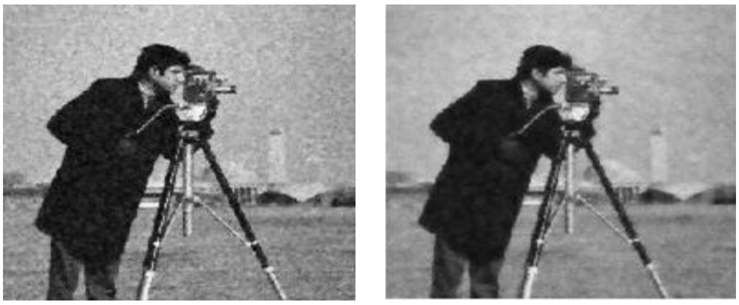
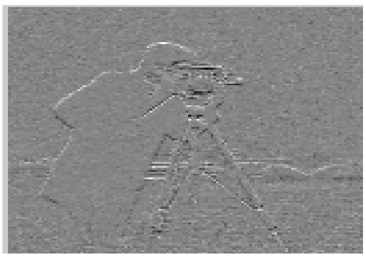


Fig 7: Guided filter output with different window size



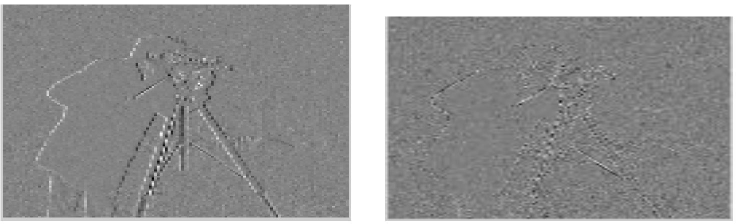


Fig 8: Wavelet coefficients after wavelet decomposition of guided filter output

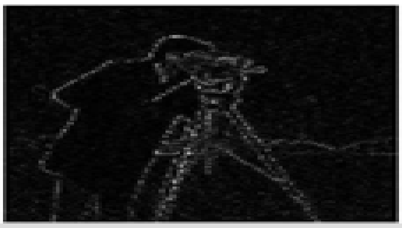


Fig 9: Wavelet based edge detected output

Fig 10: Conventional edge detetcted output

Fig 11: Variance image

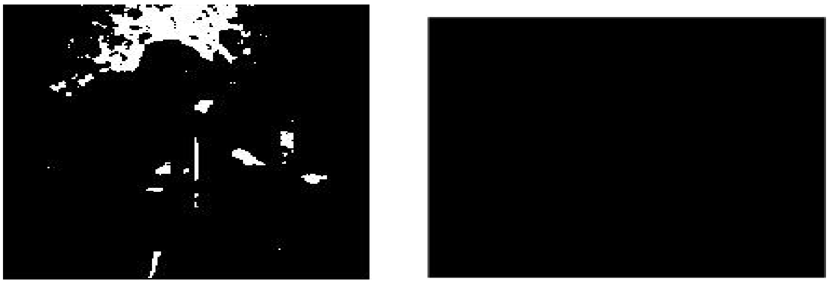


Fig 12: Separation of smooth and texture areas with different δ values

Fig 13: Morphological operation output

Fig 14: Addition of edge detected and eroded output

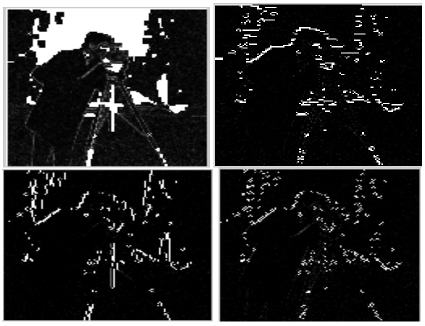
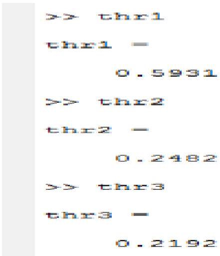


Fig 15: Wavelet coefficients of fig 17



```
>> thr1
thr1 =
     0.5931
>> thr2
thr2 =
     0.2482
>> thr3
thr3 =
     0.2192
```

Fig 16: Threshold values of different regions

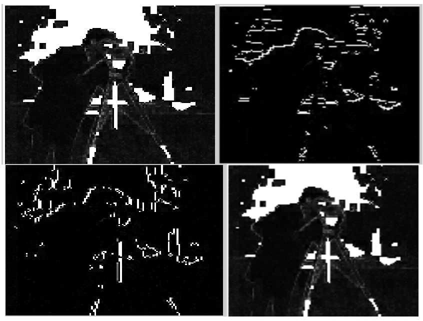


Fig 17: Thresholding of different regions with selected threshold value

Fig 18 : Inverse discrete wavelet transform output

Fig 19: Final denoised output

The quality of the denoised output is image is analyzed using Peak Signal to Noise Ratio (PSNR). A good quality image has high peak signal to noise ratio and low mean square error. The mean square error of an image is calculated using the equation (7)

$$MSE = \frac{1}{n^2}\sum_{x,y -1}^{n}(z(x,y) - s(x,y))^2 \qquad (7)$$

where z(x,y) is the estimate of the image, s(x,y) is the image without noise and n is the size of the image. The peak signal to noise ratio of an image is calculated using the equation (8)

$$PSNR = 10\log\frac{255^2}{MSE} \quad (8)$$

Table 1: Image quality analysis of different images

Original image	PSNR of Original and Noisy image	PSNR of Original and enhanced image
cameraman.tif	19.0971	20.8331
moon.tif	19.7158	21.0865
pout.tif	19.0469	21.2105
peppers.png	19.1735	22.0868
Medicalimage.jpg	19.0878	21.0538
Coins.png	19.1831	20.6314

XI. CONCLUSION

Noisy image produces undesirble visual quality which will leads to difficulty in image analysis mainly in the field of satellite and medical image analysis., where image quality is an important concern. In this work, a novel idea is proposed for the better removal of noise while preserving the edges by incorporating the concept of spatial and wavelet domain method. The quality of the proposed method is analysed on the basis of peak signal to noise ratio.

REFERENCES

[1]. M.Vijay, L.Saranya Devi and M,santhanamari "Image Denoising Based On Adaptive Spatial andWavelet Thresholding Methods" *IEEE international conference on advances in Engineering and Management (ICAESM-2012)* March 30,31 2012.

[2]. S.Grace Chang and Martin Vetterli " Spatial Adaptive Wavelet Thresholding for Image Denoising".

[3]. Aleksandra Pizurica and Wilfried Philips "Estimating probability of presence of a signal of interest in multiresolution single- and multiband image denoising" Submitted for publication to *IEEE Transaction on image processing*, May 5,2004.

[4]. Amandeep kaur and Rakesh Singh " Wavelets for Edge Detection in Noisy Images" , National Conference on Computational Instrumentation CSIO Chandigrah, INDIA, 19-20 March 2010.

[5]. D.Sripathi "Discrete Wavelet Transform" , 2003

[6]. Javier Portilla, Vasily Strela, Martin J. Wainwright, and Eero P. Simoncelli " Image Denoising Using Scale Mixtures of Gaussians in the Wavelete Domain" *IEEE Transaction on Image Processing,* Vol.12, No.11, November 2003.

[7]. Jonathan Sachs "Digital Image Basics" Copyright © Digital Light & Color 1996-1999.

[8]. Junhui Qian "Denoising by wavelet transform" Rice University Department of electrical engineering, 6100, South Main st., Houston,TX 77251-1892.

[9]. Kaiming He, Jain Sun and Xiaoou Tang "Guided Image Filtering" Department of Information Engineering, The Chinese University of Hong Kong, Microsoft Research Asia, Shenzhen Institute of Advanced Technology, Chinese Academy of sciences, China.

[10]. Lakhwinder Kaur, Savita Gupta, R.C. Chauhan " Image Denoising Using Wavelet Thresholding"

[11]. M.E Akbarpour ,M.R. Karami Mollaei " Image Enhancement by Thresholding on Wavelet Coefficients" International Journal of Soft Computing and Engineering (IJSCE) ISSN:2231-2307, Volume 2, Issue 3,July 2012.

[12]. M.Vijay,S ,V. Subha, K.Karthik "Adaptive Spatial and Wavelet Multiscale Prodeucts Thresholding Method for Medical Image Denoising." *2012 International Conference on computing, Electronics and Electrical Technologies [ICCEET].*

[13]. Richard W. Hamming , Lloyd N. Trefethen " Haar Wavelets".

[14]. Satish Pawar and V.K Banga "Morphological Image Processing" International Conference on Intelligent Computational Systems(ICICS- 2012) Jan. 7-8 2012, Dubai.

[15]. S. Grace Chang and Martin vetterli " Adaptive Wavelet Thresholding for Image Denoising and Compression" *IEEE Transaction on Image Processing,* Vol.9, No.9, September 2000.

[16]. Sudipta Roy, Nidul Sinha & Asoke K. Sen "A new hybrid image denoising method" International Journal of Information Technology and Knowledge Management, July- December 2010,Volume 2, No. 2, pp 491-497.

[17]. Yansun Xu, John B Weaver, Dennis M Haely, Jr., and Jian Lu " Wavelet Transform Domain Filters: Spatially Selective Noise Filtration Technique" *IEEE Transactions on Image Processing,* Vol. 3, No.6, November 1994.