A comparative analysis on the reconstruction of a noisy image by a hybrid filter

SaziaHassan[1], Matiur Rehman[2], Abu Rehan[3]

[1](corresponding author, M.techin ECE, Al-Falah University, Dhauj, Faridabad, Haryana, India)

[2](Asstt. Professor, Department of ECE, Al-Falah University, Dhauj, Faridabad, Haryana, India)

[3](Asstt. Professor, Department of ECE, Al-Falah University, Dhauj, Faridabad, Haryana, India)

Abstract- Digital image processing is a highly practiceable part of signal processing and in digital image processing, the removal of noise is still a challenging and popular area of research. To obtain noise free image is difficult as there are various types of noise present in the surrounding. Noise gets introduced in an image during noise acquisition and the sources are generally sensors, scanners and digital cameras. Impulse noise can be categorised as random valued impulse noise and salt & pepper noise. The present work focuses on the minimisation of salt & pepper noise. For minimising salt & pepper noise, non-linear filter is better option over linear filter. This paper presents a hybrid filter that combines both frequency domain filter as well as geometrical filter. The filter works in two steps. In the first step, the image is decomposed into high frequency and low frequency region by wavelet transform and the most informative part gets separated. In the second step, we apply median filter to modify it further. We aim to study on three types of noise as Gaussian, salt & pepper and speckle noise. The quality of the image was judged on the basis of PSNR values and RMSE values at various noise levels.

Keywords- salt & pepper noise, Gaussian noise, speckle noise, discrete wavelet transform, haar transform, median filter.

I. INTRODUCTION

Digital image processing reflects the processing on an image by the help of various computer algorithms. In this field, both input and output is in the form of image. A digital image is supposed to be composed of finite no. Of elements called pixels i.e P(x,y) where x and y are the spatial co-ordinates and the amplitude of the function resembles the intensity at that point. These pixels of the image actually gets contaminated with noise during its acquisition and transmission and so denoising of image is one of the common problem in image processing. Noise is an unwanted random signal that gets added to the image during image capturing, transmission or storage causing the variation in image intensity. The color or brightness information gets changed from that of the original thus, weakens the image appearance. The various types of noise that gets added with the image could be : Gaussian noise, impulse noise, poisson noise and speckle noise and can be minimised by different filters.

Impulse noise is a common cause for image degradation which is due to, e.g. wrong pixel elements , camera sensors, errors in analog to digital conversion, faulty memory locations in hardware transmission errors [9]. Impulse noise is classified into two main categories : fixed value impulse noise (salt & pepper noise) and random value noise [11]. The denoising of salt & pepper noise is more easy as compared to the random valued impulse noise. The salt & pepper noise are either salt (255) or pepper (0) and is also called the black and white spots on the images. Image formation process such as spreading of focal length, non-stationary camera placement cause bandwidth reduction in an image and salt & pepper noise are generally caused by camera sensors, misalligned lenses and weak focal length etc. [1]. Therefore, the suitable selection of image denoising scheme is important for salt & pepper noise.

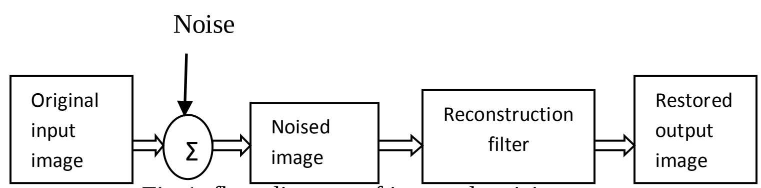


Fig.1: flow diagram of image denoising

There are various filters developed for denoising of impulse noise as linear and non-linear filters. In linear filtering technique, filter works on the whole image pixels either it is corrupted with noise or notand therefore it is more time consuming and less efficient. In non-linear filtering, the filter first of all detect the corrupted pixelsand then denoise it without touching the uncorrupted ones. Therefore it is more successful and efficient method of filtering. An image has various structural constraints, such as lines, junctions, edges, corners and other fine details [10]. However the linear filters cannot preserve these fine details, so we often prefer non-linear filtring. But now a days wavelet based denoising schemes are giving very promising results.

This paper deals with the comparative study of various noise by a hybrid filter that uses combined effect of wavelet transform of itterative noise density and median filtering [10,3].

A. WAVELET TRANSFORM

Wavelet transform is an important signal processing tool for representing signals (images) consisting mostly of slowly varying region, but containing a few fast varying regions [12]. Wavelet transform is used to represent a time domain signal into a frequency varying signal.

If x(t) be a periodic signal with period T0 and max. Frequency B(Hz) can be represented in frequency domain only by using its frequencies BT0 having harmonics k/T0 (k be any integer). If noise gets added to this signal, it can be easily removed by checking its harmonics matched with k/T0 or not [12]. The wavelet transform is a frequency-time analysis which chooses the proper frequency band on the basis of characteristics of the signal.

B. DISCRETE WAVELET TRANSFORM

When images are to be viewed or processed at multiple resolution, the discrete wavelet transform (DWT) is a mathematical tool of choice [1]. DWT provides powerful insight into an images spatial and frequency characteristics [1].

If f(x,y) is the image of size (m × n) and T(u,v,.......) be the result of discret transform, then it can be represented as [1] :

$$T(u,v,......) = \sum_{x,y} f(x,y)\, g_{u,v,......}(x,y) \quad [1].$$

Where x & y are spatial variables and u,v.......... are transferred domain variables [1].

By using DWT, the signal gets seperated into two class as low pass signals and high pass signals and each carry the information of the original signal. The low pass gives the approximation coefficients and high pass gives the detailed coefficients (vertical, horizontal and diagonal). The detailed coefficients are less informative and so set to zero. It conducts downsampling for the decomposition and upsampling for the reconstruction of the image.

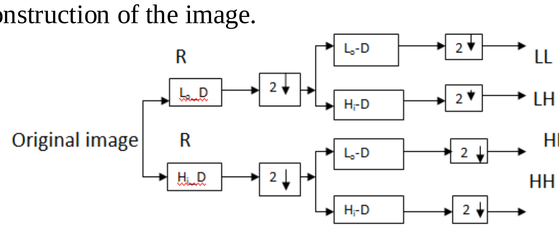


Fig.3

C. HAAR WAVELET

Haar wavelet is the oldest and simplest transformation method. The energy is very less in haar wavelet. The haar scaling and wavelet functions are discontinuous and compactly supported, which means they are 0 outside a finite interval called support [1]. In addition the haar expansion functions are orthogonal, so that the forward and inverse transformation kernels are identical [1].

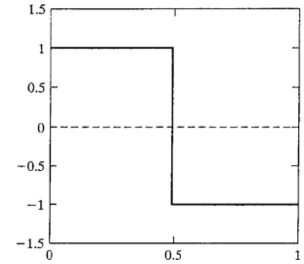
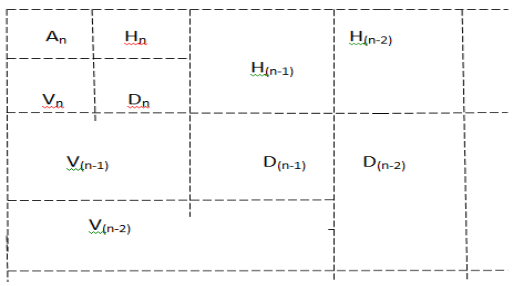


Fig.4: Haar wavelet function [1]

$\omega(m) = 1 ; \quad 0 \geq m \geq 0.5$

$-1 ; \quad 0.5 \leq m \leq 1$

$0 ; \quad$ otherwise



Fg.4: Haar wavelet decomposition

D. HYBRID FILTER

It is a combination of wavelet filter as well as median filter. Filteration by wavelet transform has already been discussed. Median filter is a type of non-linear filter often used to minimise salt & pepper noise. It preserves edges during noise reduction. The chief idea behind the successful implementation of Median filter is that it runs the signal entry by entry, replacing each entries with the median value of the encircling entries. In Median filtering, we select a particular window with the corrupted pixel and then calculate the median which then replaces the centre pixel with the median value. We repeat, it again and again until we get the rectified image. The window size can be even or odd. But to take odd no. Of window is more easy. Since, the median value is actually one of the encircled pixel, so the median filter doesnot create any new unreal pixel.

E. PROPOSED METHOD

In the concerned paper, we present a comparative study of different types of noise on an image by a filter that is a combination of wavelet transform and median filter [10]. Actually this is effective to remove the salt & pepper noise which we show here by comparing the effect of different types of noise on varying noise density. Since, the median filter is very known for its smoothness and the wavelet can successfully regain the edges. So, when both the techniques combined together they counterbalance the drawbacks of each other. This is used to arrange coefficients in a manner that enables time frequency analysis [10]. In this paper, we worked on low pass region. We tested on 'lena' and 'clock' image by decomposing using Haar transform.

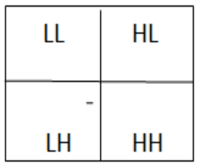


Fig.5: one level of haar decomposition

By one level haar transform, an image can be decomposed into 4 parts as LL, HL, LH, HH. For, further good results it can be decomposed many times.

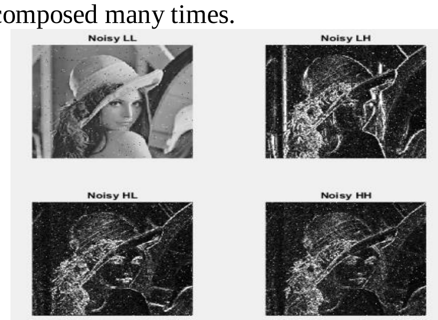


Fig.6: decomposed noisy image of LENA at low noise density

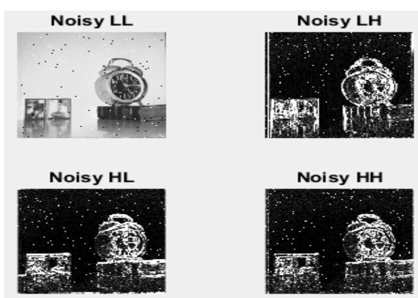


Fig.7: decomposed noisy image of CLOCK at low noise density

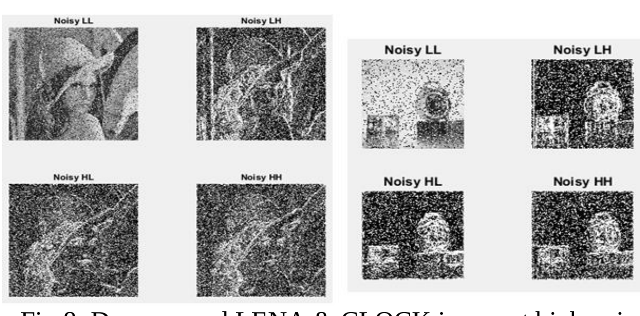


Fig.8: Decomposed LENA & CLOCK image at high noise density

The median filtering window size is taken [3 × 3]. To get better results, wavelet decomposition should be done to further more levels.Here we are concentrating on the removal of salt & pepper noise. Now for the filteration process to begin, we first use the wavelet transform to decompose the noisy image N(x,y) in the form of approximate and detailed components. Since we are working on the low pass region, the detailed component is set to zero as it contains less information regarding smoothness. After that the approximate part is median filtered [13-15]. The equation representing the method is:

$$N(x,y) = D_0[I(x,y)] + K(x,y)$$

Here N(x,y) = noised(corrupted) image

I(x,y) = original image

$D_0[I(x,y)]$ = degraded original image

K(x,y) = noise

The size of I(x,y) is given by I(x,y) ε A Ξ (1……..row) × (1…….col) is a 256×256 gray scale image.

$N(x,y) = p$ where p is the probability of noise

$= 1-p$

So, for the salt & pepper the probability of noise is p/2. The value of noisy pixel either gather 0 or 255 value. Discrete wavelet transform(DWT) of the noised image can be given :

$$W_1(x,y) = W(x,y)\, N(x,y)$$

This gives the approximate as well as the detailed (horizontal, vertical and diagonal) components as[10] :

$$W_1(x,y) = \{ A_nI , D_n^1I , D_n^2I , D_n^3I \}$$

where, A_nI = approximated coefficient of n level

D_n^1I , D_n^2I , D_n^3I = detailed coefficient of n level

The detailed coefficient ,($D_n^1I , D_n^2I , D_n^3I = 0$)

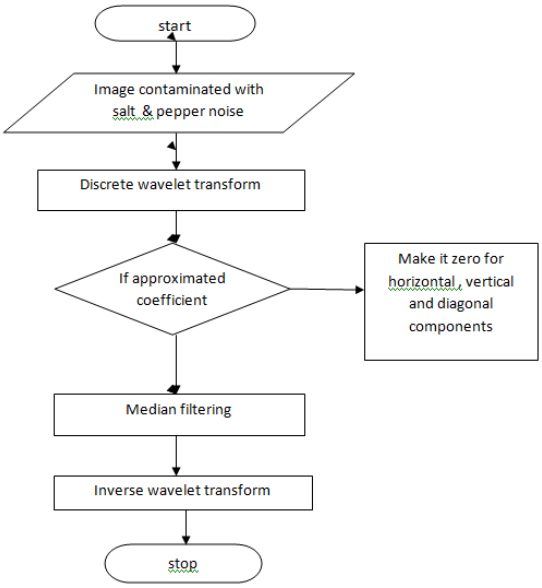
Now the approximated part is passed to median filter. The denoising is based on the neighbour pixel values. When the image gets contaminated with noise, then the noisy pixel occupies the highest or lowest pixel values. So in median filter approach the noisy pixel value is returned by the median of the encircling neighbour pixel. The noise variance is calculated as [10].

$$V' = \text{med}\{ A_1^d , A_2^d , \ldots\ldots A_N^d\}$$

Now taking the IDWT of the $W_1(x,y)$ to get the noise free pixels of the image.

$$I'(x,y) = W^T W_1(x,y)$$

The algorithm is as :



The parameters that compares the success of filter with the respective noise are:

1) Mean square error (MSE)

$$= 1/\square\square \sum_{\square=0}^{\square-1}\sum_{\square=0}^{\square-1}[\square(\square,\square) - \square'(x,y)]^2$$

2) Peak signal to noise ratio

$$= 20\log 10 \frac{255^2 JK}{\sum_{\square=0}^{\square-1}\sum_{\square=0}^{\square-1}[\square(\square,\square) - \square'(x,y)]^2} \text{ db}$$

II. SIMULATION AND RESULT

The suggested method was executed using MATLAB R2017a using DELL laptop having 4GB RAM, core i5 (7^{th} gen.) processor using windows 10 OS.

The imitation part consists of the comparative study of salt & pepper noise over all the three noises. The filteration part gives the result with and without using hybrid filter. Median filter works with mean value as zero and variance approximated nearly 0.01 to 0.19 for which 0.02 is the fixed intemission of all the 11 iterations.

While giving the mathematical model of combined approach, we examined the performance of the filter with haar wavelet and median filter on both 'lena' and 'clock' images from fig : 9-14.

Table 1: Simulation parameters

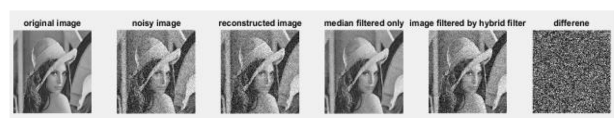
Se. no.	Parameters	Specification
1.	Type of noise	Salt & pepper
2.	Name of wavelet	Haar wavelet
3.	Level of decompose	1
4.	Filter (size)	Median filter(3×3)
5.	No. of iteration	11
6.	Noise mean(μ)	Zero
7.	Noise density	0.01 to 0.19

(a´) 0.01 noise density

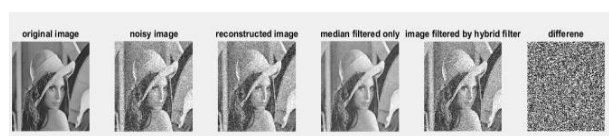
(b´) 0.09 noise density

(c´) 0.19 noise density

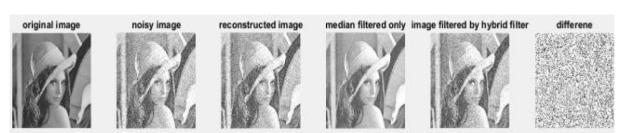
Fig.9: (a´), (b´), (c´) shows the reconstruction of corrupted salt& pepper noise(SPN)



(a´) 0.01 noise density

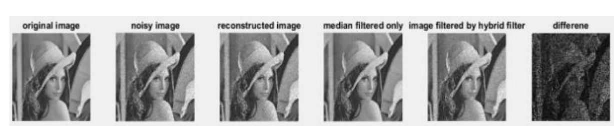


(b´) 0.09 noise density

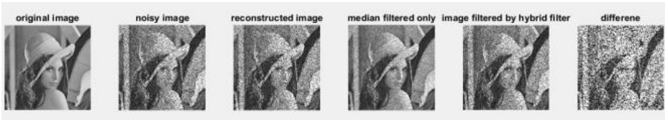


(c´) 0.19 noise density

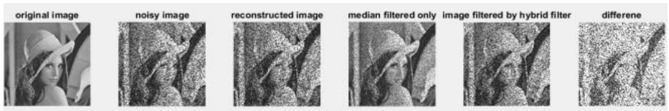
Fig.10: (a´), (b´), (c´) shows the reconstruction of corrupted Gaussian noised image



(a´) 0.01 noise density



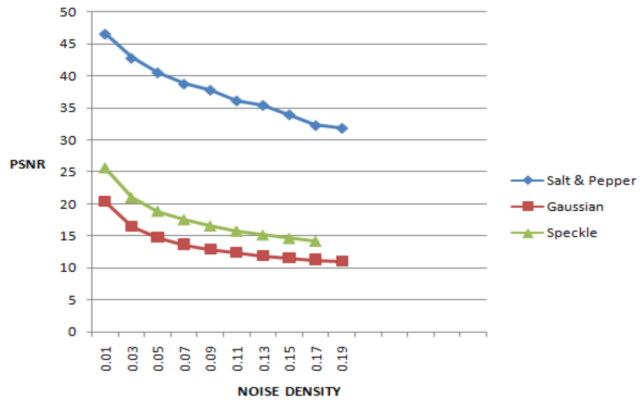
(b´) 0.09 noise density



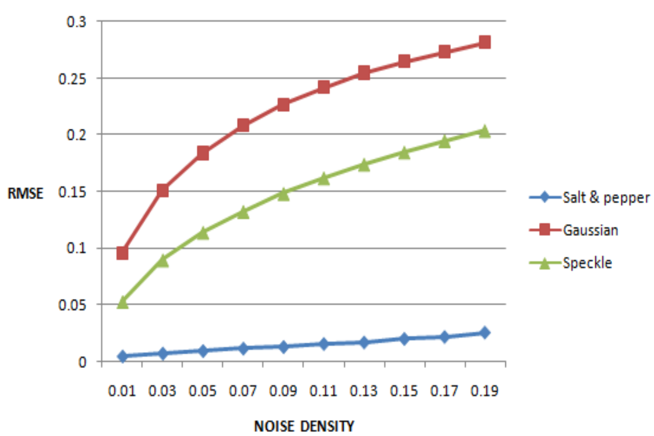
(c´) 0.19 noise density

Fig.11: (a´), (b´), (c´) shows the reconstruction of corrupted speckle noised image

It is formulated that as the noise density increases, salt & pepper noised affected image is regained better than other noise types. Smoothness is not gained in a better manner as we move from salt & pepper noise to Gaussian and speckle noise. The graph between PSNR and RMSE vs noise density gives the clear view.

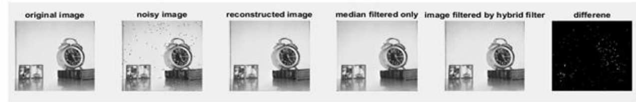


(a)

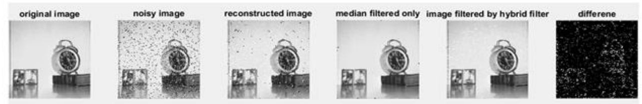


(b)

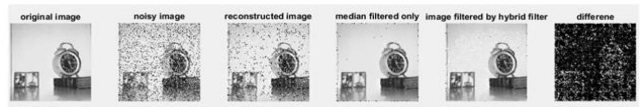
Fig.12: (a) psnr vs noise density (b) rmse vs noise density plot of LENA image for different noise



(a)



(b)



(c)

Fig.14: performance of clock image on increasing noise denity for salt & pepper noised image

The simulation parameters has been explained in table 1. The algorithm displays the low frequency and edges characteristics because it considers only approximate part of the signal. As per this paper, the proposed filter concerns with different noise models for a standard lena and clock image. It is clearly viewed that as we increase the noise density, the evenness of the filtered image is preserved with edges as well using small window (i.e. 3×3) median filter and one level of haar decomposition. As we increase the window size of median filter e.g (5×5),the PSNR doesnot change so much, however the picture quality degrades. This is shown by the given figures and plots.

(3×3) window median filter

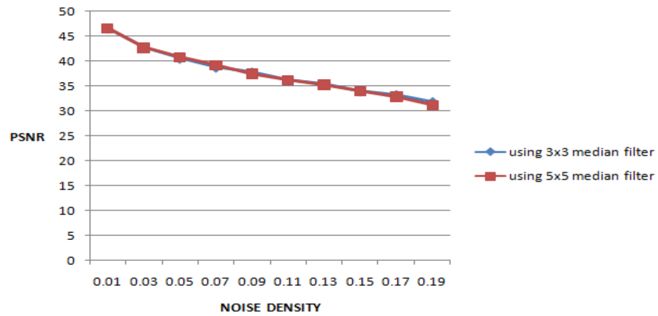
(5×5) window median filter

Fig.13:performance of median filter at low noise density

(3×3) window median filter

(5×5) window median filter

Fig.14: performance of median filter at low high density



It can be clearly evaluated that as the window size increases, the PSNR more or less overlaps but the image visual quality degrades at higher noise level.

From figure: 9-11, it is observed that for the Gaussian noise the smoothness goes while denoising and for speckle noise even the picture quality is worst. But the salt & pepper noise filteration is good with respect to edges as well as smoothness. The comparission can be seen from the psnr and rmse plot also in fig: 12.

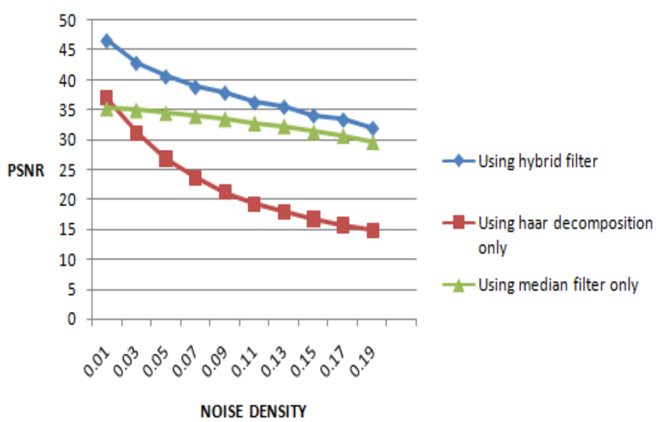


Fig.15: comparission of image quality using different filtering methods

Fig:15 shows the complete comparison of image filtering by different filters and observed that hybrid filter works better than the traditional median filter.

III. CONCLUSION

From the proposed comparative study of all the three noise types on LENA from fig : 9-11, the image quality is better in case of salt & pepper noise as noise density increases from 5% to 100%. The detailed wavelet coefficients have been suppressed and the results have been calculated by considering the approximated coefficients only without any thresholding. The performance is compared on the basis of psnr and rmse values as shown in fig : 12.

The low noise density achieved notable and astonishing results. But in application as there is increase in noise from 47% to 100% , the suggested algorithm gives promising results as in fig: 9-11. For the greater window size, the noise gets little reduced as the psnr plot almost overlaps each other but the image is more blurred.

This implies that the combined effect of median filter and wavelet transform worked well for salt & pepper noise removal over the other two noise.

IV. FUTURE WORK

From this approach, the image can gets better and better if we decompose the image further and further. But to get rid of this, a limited decomposition approach with the best image quality and frequency threshold can also be made of.

V. REFERENCE

[1]. R.C.Gonzalez and R.E.Woods,"Digital image processing", second ed.Prentice Hall, Englewood, Englewood, Cliffs, NJ, 2002.

[2]. S Mallet "A Wavelet Tour of Signal Processing", Academic Press, New York, 1998.

[3]. A. Boyat and B.K.Joshi, "Image denoising using wavelet transform and Median Filtering", In press, IEEE Nirma University I nternational Conference on Engineering, Ahmedabad, 28-30 November 2013.

[4]. S. Salivahanan, A. Vallavaraj and C. Gnanapriya " Digital Signal Processing, " Tata Mcgraw-Hill, vol.23, New Delhi,2008.

[5]. R. C. Gonzalea, "Image Restoration and Reconstruction",in Digital Image Processing, 3rd ed. India: Pearson Prentice Hall, pp. 322-330, 2011.

[6]. M.A.Pasnur and P.S.Malge," Image Retrieval Using Modified Haar Wavelet Transform and K Means Clustering" International Journal of Emerging Technology and Advanced Engineering, vol.3, issue 3, March 2013.

[7]. S.H.Teoch and H. Ibrahim "Median Filtering Frameworks for Reduction Impulse Noise fromGrayscale Digital Images: A Literature Survey ",International Journal of Future Computer and Communication, vol.1, no.4, December 2012.

[8]. A.Fathi and A.R.N.Nilchi," Efficient Image Denoising Method Based on a New Adaptive Wavelet Packet Thresholding Function," IEEE Trans. Image Processing, vol.4, no.9, September 2012.

[9]. Sciacchitano. F (2017)." Image Reconstruction Under Non-Gaussian Noise", Kgs. Lyngby: Technical University of Denmark (DTU), DTU compute PHD-2016, No. 426.

[10]. Arpita Joshi, Ajay Kumar Boyat , Bijendra Kumar Joshi, "Impact of Wavelet Transform and Median Filtering on Removal of Salt & Pepper Noise in Digital Images", International Conference on Issues and Challenges in Intelligent Computing Techniques (ICICT)", 2014.

[11]. TraptiSoni and Mrs. Vaishali Joshi," A Comparative Performance Analysis of High Density Impulse Noise Removal Using Different Types of Median Filters", International Journal of Computer Science Trends and Technology(IJCST)- volume 2 issues 6, Nov-Dec 2014.

[12]. Andrew E. Yagle and Fawwaz T. Ulaby," Image Processing for Engineers" Published in the United States of America by Michigan Publishing, Manufactured in the United States of America (2018) Website: ip.eecs.umich.edu

[13]. S.H.Teoch and H. Ibrahim," Median Filtering Frameworks for reduction Impulse Noise from Grayscale Digital Images : A Literature Survey", International Journal of Future Computer and Communication, vol.1, no. 4, December 2012.

[14]. T. Kaur, M. Sandhu and P.Goel,"Performance Comparission of Transform Domain for Speckle Reduction in Ultrasound Image", International Journal of Engineering Research and Application, vol.2, issue 1, pp.184-188.

[15]. P. Subashini, M. Krishnaveni, B.K.Ane and D.Roller," Image Denoising Based on Wavelet Analysis for Stellite Imagery", Soft Computing Models in Industrial and Environmental Applications, Springer jth International Conference, SOCO'12, Ostrava, Czech Republic,pp.399-407, September 5th_7th, 2012-13.