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Survey of Image De-Noising Techniques for Radiographic Images of Cold Trap

[1]B. Thamotharan, [1]V. Vaithiyanathan, [2]B. Venkatraman, [1]Akshaya Prakash,
[1]Anurag Singh and [3]M. Menaka
[1]School of Computing, SASTRA University, India
[2]Radiologcal Safety and Environment Group,(RSEG), IGCAR
[3]QAD, IGCAR, India

Abstract: Digital Image Processing is processing on the digital images by means of different algorithms. A digital image can be of different types such as RGB, grayscale, radiographic images etc. All kind of images have some of noise (s) captured by capturing devices because of atmospheric conditions, incorrect photon count because of electromegnetic interference etc. This study is based on radiographic image denoising with several techiques in spatial domain, frequency domain, wavelet domain. This study presentsthe result of comparitive study on different filters available in different domains and their PSNR values. This study shows the effect of mask size on each filter and thus gives an idea for the proper selection of size of mask (square) for a filter to get better result.

Key words: Filters, global soft thresholding, MSE, PSNR, spatial and frequency domain, wavelet

INTRODUCTION

Digital images are getting important role in our daily life applications like medical field, satellite field and also in research area. In this area most of the important data which are collected from the images by image sensors are usually contaminated by noise. Removing noises from image is a challenging task for researchers even till date. There have been various approaches and techniques which has its own limitations and advantages.

This study presents review and presents the result of some of the significant works in the concept of de-noising of Radiographic (RG) Images. Radiography is the process to produce an image of non-uniformly composed materials using X-rays or gamma rays. Radiographic images are sources of abundant information which can be used in detection of the presence of various elements and compounds in a given image. This technique has been applied in many fields, for example to detect the various types of gases present in the atmosphere of sun and many other planets, detection of minerals ores based on special images of satellites of any area etc. Before getting data from an image, removal of noises from the image is necessary and thus becomes the first step in image processing (Gonzalez and Woods, 2001). The sources of noises here may be wrong angle for the capturing device with the surface of specimen or the poorer quality technique (Gonzalez and Woods, 2001). The techniques for removal of noise should be applied carefully; otherwise noise removal introduces artefacts which cause blurring of the image and there by degrading the quality of original image (Gonzalez and Woods, 2001). The image is affected by many factors like image quantization, data transmission and media capturing instruments.

Removal of noises from an image is the fundamental problem in the field of image processing. Most of the RG images are assumed to have additive random noises. This study mainly focuses on noise removal techniques in radiographic images of cold trap. Cold traps are devices which are employed in sodium system of Fast Breeder Test Reactors' (FBTR) (Suresh Kumar *et al*., 2003) in the atomic field for maintaining the oxygen/hydrogen level in sodium within acceptable limit. This study describes the application of various filter technique to remove noises and uses PSNR (Gonzalez and Woods, 2001) value to compare results obtained.

Here all the images are gray scale radiographic images obtained by using Gamma Rays. Gamma ray or Gamma Radiation is electromagnetic radiation emitted during radioactive decay and having high frequency and short wavelength. It has highest frequency and energy (above 10 exaHertz and 10 Kev) (Experimental observation, (Baryshevsky *et al*., 2007). The random noises in radiographic images are positive impulse noise, Gaussian noise, scattering noise etc. (Chen and Hongnian, 2000). Here impulse noise is a particular type of interference caused by sources such as electrical machinery. The other possible noises are film grain noise,

Corresponding Author: B. Thamotharan, School of Computing, SASTRA University, India,

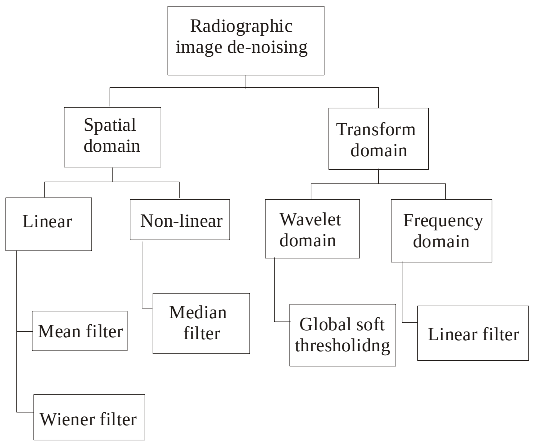


Fig. 1: Image de-noising techniques

electronic noise in digital radiographic images. All these noises come under the classification of random noise model. These noises affect the imaging quality seriously. The aim of image de-noising is to restore the image corrupted by noise as close as possible to the original one (Gonzalez and Woods, 2001).

This study presents the results obtained from various filters for de-noising of radiographic images and they have been compared using PSNR value.

PSNR (PEAK SIGNAL TO NOISE RATIO)

PSNRis the ratio of maximum possible power in image to the noise quantity in the image. Mathematically represented as:

$$PSNR = 10.\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right)$$

where,

MAX_I is the maximum possible pixel value in the image,
MSE is the mean-square-error in the images (original and denoised) (Gonzalez and Woods, 2001)
MSE is repesnted mathematically as:

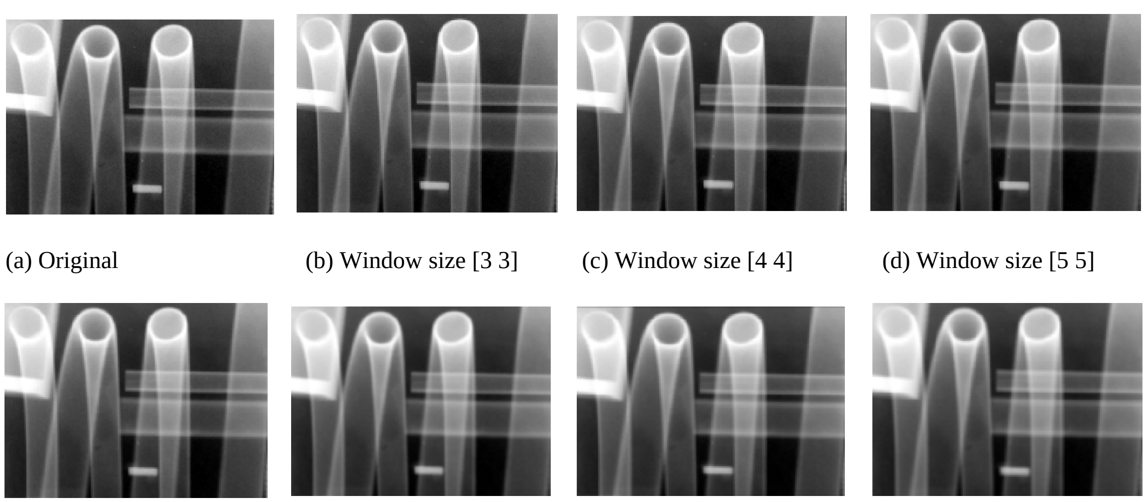
$$MSE = \frac{1}{m \times n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[I(i,j) - K(i,j)\right]^2$$

I (i, j) represents the pixel value at coordinate (i, j) of the image '*I*'.

Unit of PSNR is in 'db'. When the both images are exactly same, then MSE will be zero. And this gives PSNR value equals to infinity (∞).

Classification of de-noising techniques: There are two basic approaches for image de-noising. They are spatial domain filtering methods and transform domain filtering methods. Spatial Filtering is the traditional method to remove noise from image. Spatial domain filter can be further classified into non-linear spatial filter and linear spatial filter. Under spatial domain linear filter two filtering techniques have been used here. They are linear mean and linear wiener.

Transform domain filtering can be subdivided into frequency domain filtering and wavelet domain filtering (Fig. 1).



(a) Original (b) Window size [3 3] (c) Window size [4 4] (d) Window size [5 5]

(e) Window size [6 6] (f) Window size [7 7] (g) Window size [8 8] (h) Window size [9 9]

Fig. 2: After applying mean filter on same image with different window size

Table 1: PSNR values for different window size for mean filter

Window	PSNR
[3 3]	35.7781
[4 4]	33.0799
[5 5]	32.7223
[6 6]	31.2646
[7 7]	30.6963
[8 8]	29.6682
[9 9]	29.0501

SPATIAL DOMAIN FILTERS

Linear filters:

Mean filter: Mean filter is the optimal filter for removing grain noise (Patidar *et al*., 2010) in an image. The Mean Filter is a linear filter which uses a mask over each pixel in the image. Each of the components of the image which fall under the mask are averaged together to form an output pixel. This filter is also called as average filter. Linear mean filter becomes weak when the noise in the image is adaptive noise (Gonzalez and Woods, 2001). Here, this filter has been applied in radiographic images and the PSNR value is obtained. Generally this filter is applied for noise suppression. Mathematically:

$$f(x, y) = \frac{1}{m \times n} \sum_{i=0}^{i=m} \sum_{j=0}^{j=n} f(i, j)$$

where,

m, n being the window size parameters,
$f(x, y)$ represents the value of the central pixel of the image under the window,
$f(i, j)$ represents the pixel value of the image under the window coordinate (i, j) (Fig. 2).

Results: Table 1 represents the PSNR values of mean filtered images with respect to different window size of mean filter applied to the same image. And by these values a graph has been plotted out as shown in Fig. 3 and the graph has been analysed as follows.

Analysis:

- On increasing window size the PSNR ratio will decrease in Mean Filter.
- Lower the PSNR, means more data change has been occurred (including noise, blurring etc.).
- Increasing windows size may blur the image. So it should be carefully used.

Wiener filter: Wiener Filter (Patidar *et al*., 2010; Jain, 1989) works in spatial domain linearly. Wiener filter is used when the noise in image is a constant power additive noise (Patidar *et al*., 2010). Such noise is present in blurred images. Wiener filter calculates the local mean and variance around each pixel (Jain, 1989). Wiener filter is applied on an image pixel wise, throughout the image using adaptive wiener filtering. Applying a wiener filter to an image does pixel wise adaptive wiener filtering throughout the whole image (MathsWork.inc). Mathematically wiener filter is governed as:

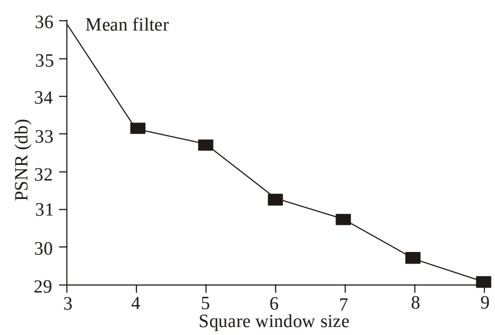
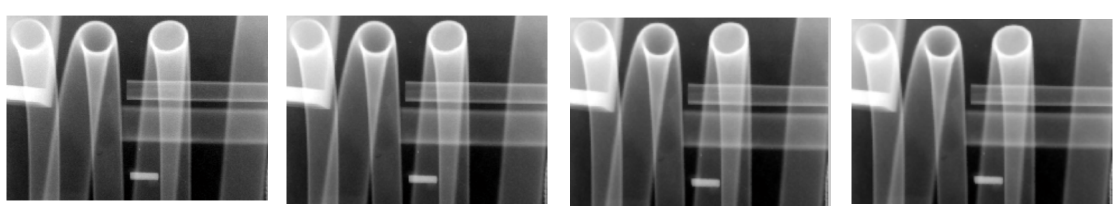
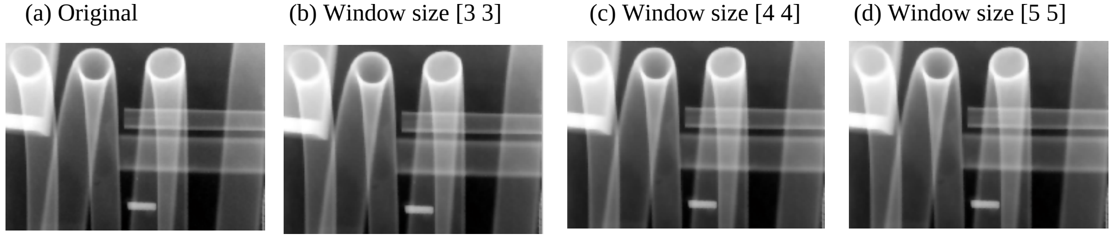


Fig. 3: PSNR (db) vs square window size for mean filter



(a) Original (b) Window size [3 3] (c) Window size [4 4] (d) Window size [5 5]



(e) Window size [6 6] (f) Window size [7 7] (g) Window size [8 8] (h) Window size [9 9]

Fig. 4: After applying wiener filter on same image with different windows size

Table 2: After wiener filter on same image with different window size

Window	PSNR
[3 3]	42.9637
[4 4]	39.5423
[5 5]	39.3962
[6 6]	37.7738
[7 7]	37.2673
[8 8]	36.1546
[9 9]	35.5266

$$b(n_1,n_2) = \mu + \frac{\sigma^2 - v^2}{\sigma^2}\big(a(n_1,n_2) - \mu\big)$$

where,

μ being The local mean around each pixel
σ^2 being The local variance around each pixel
v^2 being The noise variance:

$$\mu = \frac{1}{NM}\sum_{n_1,n_2\in\eta} a(n_1,n_2)$$

$$\sigma^2 = \frac{1}{NM}\sum_{n_1,n_2\in} a^2(n_1,n_2) - \mu^2$$

If the noise variance is not given, wiener filter uses the average of all the local estimated variances.

In this study, only square window or mask has been used. For such window both ‘m’ & ‘n’ will be same, say ‘n’ (Fig. 4).

Results: Table 2 represents the PSNR values of wiener filtered images with respect to different window size of wiener filter applied to the same image. And by these values a graph has been plotted out as shown in Fig. 5 and the graph has been analysed as follows.

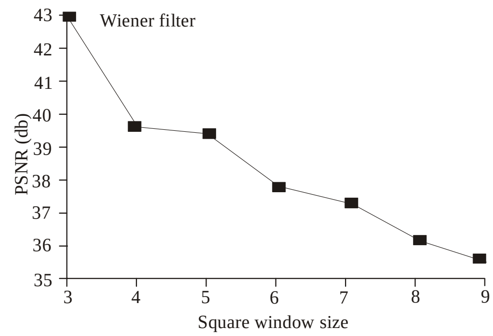
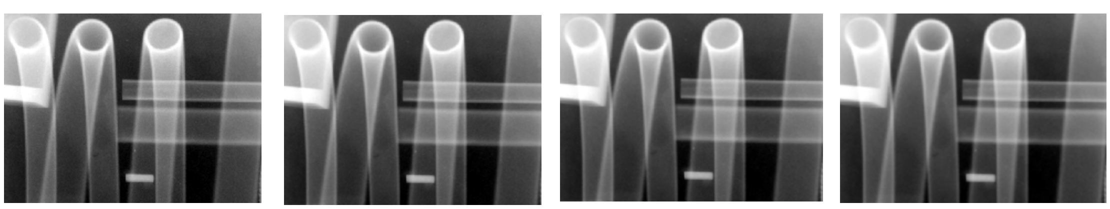


Fig. 5: Graph of PSNR (db) vs square window size for wiener filter

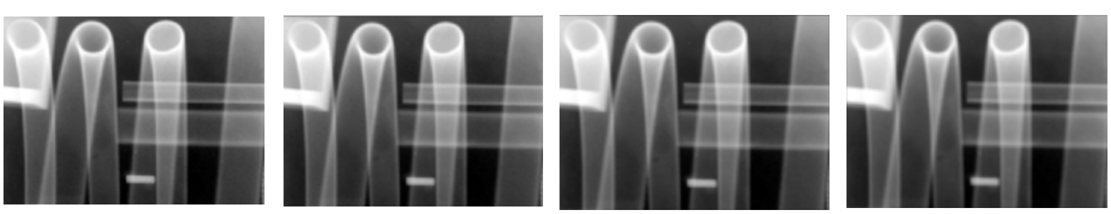
Analysis:

- By analysing the above graph it can be concluded that increasing the window size for wiener filter reduces the PSNR ratio and removes more noise.
- But increasing the window size may lead to distortion in the edge, hence it should be carefully used.

Ones filter: Ones filter is not an available predefined filter. This is a user defined filter which may be used to remove black noise from the images and it can be used to blur the images if they are already much sharpen. It is a linear filter and has much effect on edges than the wiener filter. An ones filter of window [3 3] which we used can be represented as:



(a) Original (b) Window size [3 3] (c) Window size [4 4] (d) Window size [5 5]



(e) Window size [6 6] (f) Window size [7 7] (g) Window size [8 8] (h) Window size [9 9]

Fig. 6: After applying ones filter on same image with different window size

Table 3: PSNR values for different window size for ones filter

Window	PSNR
[3 3]	35.7781
[4 4]	33.0799
[5 5]	32.7223
[6 6]	31.2646
[7 7]	30.6963
[8 8]	29.6682
[9 9]	29.0501

$$\begin{bmatrix} \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \end{bmatrix}$$

Ones filter of size [m m], has been used, such that it is a matrix of m rows and m columns and each of its entry is equal to reciprocal of m^2 (Fig. 6).

Results:

Table 3 represents the PSNR values of ones filtered images with respect to different window size of ones filter applied to the same image. And by these values a graph has been plotted out as shown in Fig. 7 and the graph has been analysed as follows.

Analysis*:*

- Increasing the size of window for ones filter will decrease the PSNR ratio always.
- But one's filter may lead to blurring of image while increasing the window size.
- Ones filter lead to distortion in the edges.

Note that ones filter should be applied only in desired situations when blurring of the imagedoes not impact the goal of process.

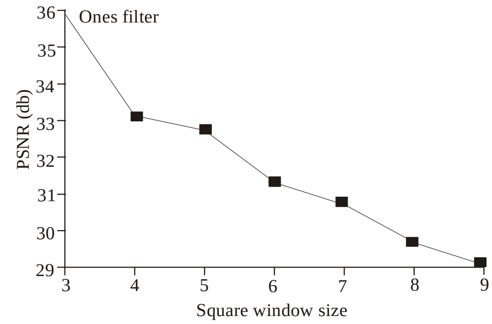


Fig. 7: Graph of PSNR (db) vs square window size for ones filter

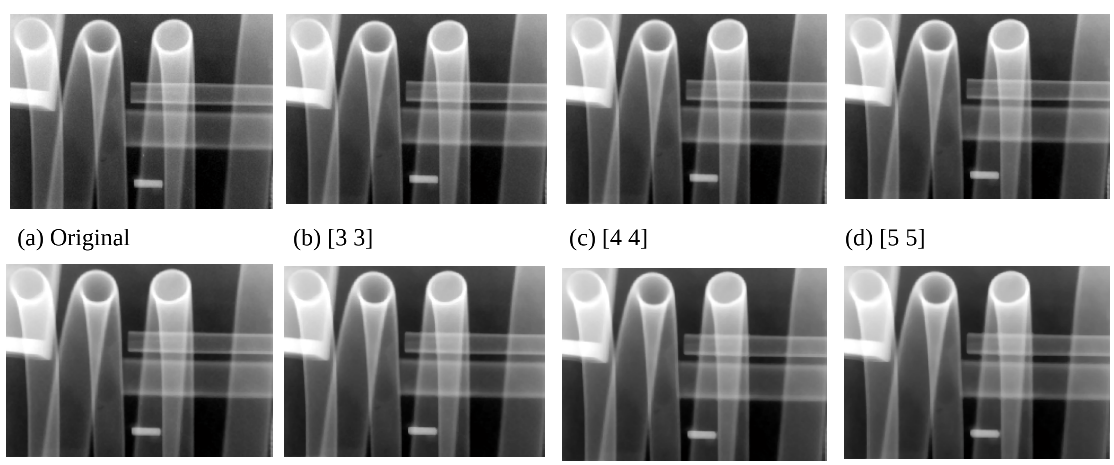
Non linear filters:

Median filter: Median filter (James *et al*., 2008) comes under the category of non-linear filter. It is very famous filter in digital image processing. Unlike that of mean filter, it takes median of neighbouring pixels. Median filter is often used when the noise in image is of type 'salt and pepper' (Alan, 2005). Median filter is used to simultaneously reducing noise and preserving the edges (MathsWork.inc). Median filtering is therefore better able to remove these outliers without reducing the sharpness of the image (Fig. 8).

Results: Table 4 represents the PSNR values of median filtered images with respect to different window size of median filter applied to the same image. And by these values a graph has been plotted out as shown in Fig. 9 and the graph has been analysed as follows.

Analysis:

- By analysing the above graph it can be said that increasing the window size does not always decrease the PSNR ratio.



(a) Original (b) [3 3] (c) [4 4] (d) [5 5]

(e) [6 6] (f) [7 7] (g) [8 8] (h) [9 9]

Fig. 8: After median filter on same image with different window size

Table 4: PSNR values for different window size for median filter

Window	PSNR
[3 3]	42.2295
[4 4]	34.1317
[5 5]	38.3716
[6 6]	33.3135
[7 7]	36.2784
[8 8]	32.4618
[9 9]	34.4992

Table 5: PSNR values at different level for each wavelet for a image

Wave name	Levels				
	2	3	4	8	16
‘ haar ’	36.6511	35.8555	35.5623	35.4248	35.4247
‘db1’	36.6511	35.8555	35.5623	35.4248	35.4247
‘db3’	39.2449	38.0756	37.6655	37.4534	37.4529
‘db10’	39.6159	38.0799	37.5557	37.3379	37.3373
‘coif1’	38.9983	37.9951	37.5968	37.415	37.4144
‘coif3’	39.6524	38.2521	37.7466	37.5462	37.5457
‘sym2’	38.8198	37.8804	37.4127	37.2173	37.2172
‘sym4’	39.4787	38.1916	37.7368	37.52	37.517
‘sym8’	39.6841	38.2216	37.7845	37.5533	37.5519
‘dmey’	39.7931	38.2439	37.7638	37.5297	37.528
‘bior1.1’	36.6511	35.8555	35.5623	35.4248	35.4247
‘bior1.3’	36.732	36.0557	35.8968	35.8561	35.8571
‘rbio1.1’	36.6511	35.8555	35.5623	35.4248	35.4247
‘rbio1.3’	39.0988	37.7172	37.2533	37.0091	37.0055

- On increasing the window size from odd to even, the PSNR ratio decreases, while if the window size is increased from even to odd, the PSNR ratio increases.
- The PSNR value decreases for the next even size filter as compared to that of the last even sized window. The same behaviour is observed for the odd sized window.
- Median filter preserves edges compared to mean filter.

Transform domain:

Global thresholding in wavelet domain: Wavelet transform represents signal in a high degree of scarcity (Donoho, 1995). Wavelet thresholding is the way to de-noise an image using wavelet transformation of the image. Wavelet transformation has very good localization property. Wavelet de-noising preserves the signal characteristics and removes lots of noise from the signal. Thresholding is the boundary limit for noise and signal content separation. In this study soft global thresholding has been used. Usually soft thredholding is used because of its merit. In this study transformation of original image in wavelet domain has been done by using discrete wavelet transformation. To represent an image in wavelet domain, several waves are available namely ‘haar’, ‘db1’ etc. A level up to which decomposition of the original image has to be done is selected in wavelets. Then a default global soft thresholding is applied to the image in wavelet domain. The idea behind de-noising is that the regular pixel values in the image can be accurately

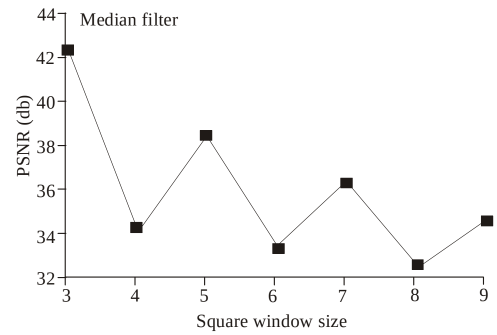


Fig. 9: Graph of PSNR (db) vs square window si median filter ze for

approximated by a small number of approximation coefficients for a given level and some of the detail coefficients (Gonzalez and Woods, 2001; Donoho, 1995).

In this study, different waves for transformation have been chosen and their outputs have been compared using the PSNR value of the result. It is possible that blurring, artefacts may appear if the technique is not chosen in a right optimal way. Inspired by the work of Donoho (1995) the global soft thresholding has been preferred for this study. The wavelet de-noising algorithm by the Mathworks (MathsWork.inc) has been utilised.

Results: Table 5 represents the PSNR values of filtered images in wavelet domain with respect to different wavelets and levels used to de-noise the same image. And by these values a graph has been plotted out as shown in Fig. 10 and the graph has been analysed as follows.

Analysis: (For particular given image)

- ‘haar’ wavelet gives lowest PSNR ratio for all levels.
- ‘haar’, ‘db1’, ‘bior1.1’ and ‘rbio1.1’ give equal PSNR ratio for all levels.
- After level 8 the PSNR value for all the wavelets becomes almost constant.
- ‘dmey’ wavelet gives higher PSNR for level below than 8.
- ‘sym8’ wavelet gives higher PSNR for level 8 and more.

Frequency domain: An image is represented as a matrix with entries as pixel values. Thus an image found is called image in spatial domain. By using a 2-D discrete Fourier transformation on image matrix another matrix was can be equated, which is called image in frequency domain. Various filters can be applied in spatial as well as in frequency domain for de-noising of an image. 2-D discrete Fourier transform (Gonzalez and Woods, 2001) and inverse Fourier transform is represented mathematically as:

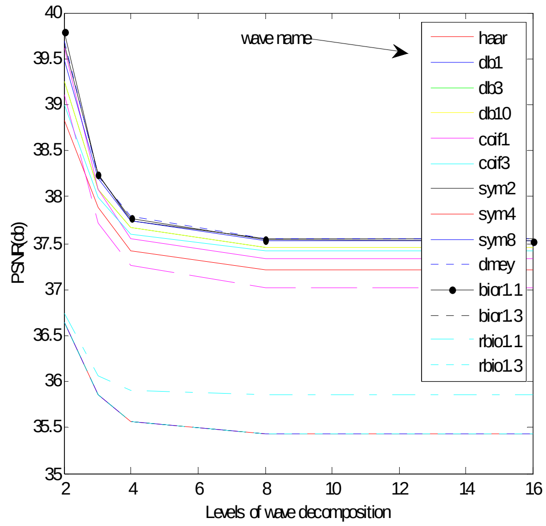
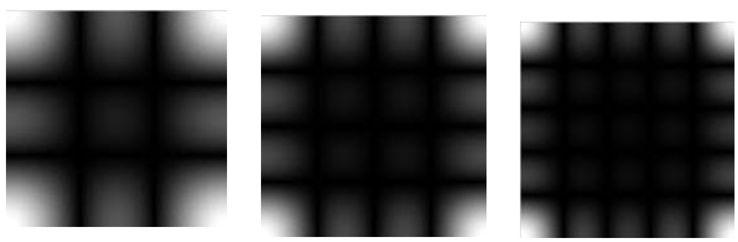


Fig. 10: Graph of PSNR values at different levels for different wavelets



(a) (3, 3) (b) (4, 4) (c) (5, 5)

Fig. 11: Freque ones (3, 3) (4, 4) and (5, 5) ncy response of

$$F(u,v) = \frac{1}{MN}\sum_{x=0}^{M}\sum_{y=0}^{N} f(x,y)\cdot e^{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)}$$

$$f(x,y) = \sum_{u=0}^{M}\sum_{v=0}^{N} F(u,v)\cdot e^{j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)}$$

Here, f (x, y) is the pixel value at coordinate (x, y) in spatial domain and F (u, v) is the frequency response at coordinate (u, v) in frequency domain.

Image de-noising filters can be applied on images in frequency domain and the output is again converted back into the spatial domain by using inverse Fourier transform.

Here one's filter (the same used in spatial domain filtering), has been applied in frequency domain and then the results have been compared using PSNR values.

Results: Figure 11 represents the frequency response of ones filter of different window size in frequency domain Table 6 represents the PSNR values of ones filtered. images in frequency domain with respect to different

Table 6: PSNR values for different window size for ones filter in frequency domain

Window	PSNR
[3 3]	35.7781
[4 4]	33.0799
[5 5]	32.7223
[6 6]	31.2646
[7 7]	30.6963
[8 8]	29.6682
[9 9]	29.0501

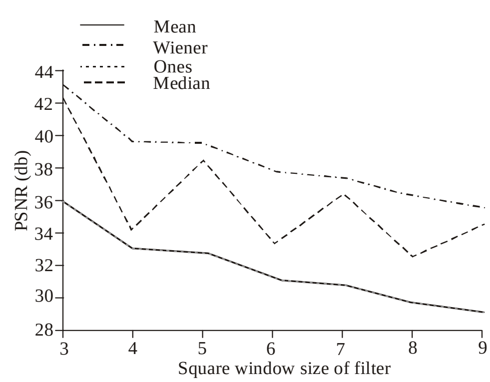


Fig. 12: PSNR (db) values of different window size for different filters

window size of ones filter applied to the same image. And by these values a graph has been plotted out as shown in Fig. 12 and the graph has been analysed as follows.

Analysis:

- Linear filters applied in spatial or frequency domain will give the same PSNR in both domains if the filter applied is same.
- The reason behind this is the basic property of Fourier transform which says, Fourier transform of a convolution pair is equivalent to multiplication of individual Fourier transform of convolving functions.
- PSNR is decreasing on increasing the size of window.

CONCLUSION

- Non-linear filters operate better than linear filters.
- A graph showing different PSNR values of different filters is given below.

By the above plot it can be concluded that for the given image, mean and ones filter gives the same PSNR value which is lesser than the PSNR values for Wiener and median filter.

- Median filter is much better than mean and Wiener filter because it does not take extra padded values over the edges and thus removes noises with a very little affect on the edges (Jain, 1989).
- Wavelet global soft thresholding is a very good technique for de-noising purpose and it gives a better idea to sub bands of images.
- Here it can be observed that the PSNR values for Ones filter in both Spatial and Frequency domain is same. This proves fundament Convolution Theorem (Gonzalez and Woods, 2001) which is represented as:

$$f(x, y)*h(h, y) \leftrightarrow F(u, y)H(u, v)$$
$$f(x, y)h(h, y) \leftrightarrow F(u, v)*H(u, v)$$

Here '*' denotes the convolution of two function.

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