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An Analytical Study of Spatial Domain Image Denoising Techniques

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***Abstract*—Digital images are very important part in applications and technology .In digital images noise is introduces during transmission and capturing process. due to adding noise the quality of image is degraded so the challenge is to remove noise from the original image. This paper reviews the comparative study of spatial domain filters, different types of noises and quality measures. there are many filters proposed for image de-noising but each technique has its advantages and overcomes. basically there are two types of denoising techniques. One is spatial domain filtering and other is transform domain filtering. In this paper we study about which filtering techniques best for different noise and comparing techniques in terms of psnr and mse.**

Keywords—*Image Denoising; Noise Models; Spatial Domain Filters; Linear filters; Non-linear filters; Quality performances.*

I. INTRODUCTION

In digital world, Digital Images play an important role in daily applications such as Magnetic Resonance Imaging, Satellite Television and technology including Geographical Information System. Noise is unwanted signal introduces during transmission and capturing process and degraded the quality of image [6] . The sources of noise in images are imperfect hardware, during acquisition process, transmission and compression . Image denoising is a process of removing the noise. There are different types of image noises present in the image like Additive noises and multiplicative noises. additive is additive in nature and multiplicative noise multiple in nature. There are many techniques for image denoising but two are basictechniques they are spatial domain image denoising and transform domain image denoising. the best image denoising techniques is that remove noises without blurring the image. this paper described sources of noise, types of noises ,different Spatial domain denoising techniques and image quality measure and comparison of techniques.

II. Noise Model

The source of noise in digital images arises during image acquisition and transmission. Image sensor is affected by variety of reasons such as environmental condition during image acquisition, sensor temperature and light levels. basically There are two types of noise models are additive types noise model and multiplicative types noise model [6].

Additive noise:
In this model: In this noise model the noise is add with pixel of image. it is defined by,

$$z(x, y) = f(x, y) + n(x, y) \tag{1}$$

z(x, y) is degraded image, f(x, y) is original image and n(x, y) is noisy image.

Multiplicative noise model:
In this noise model the noise is multiply with pixel of image. it is defined by,

$$z(x,y) = f(x,y) * n(x,y) \tag{2}$$

z(x, y) is degraded image, f(x, y) is original image and n(x, y) is noisy image.

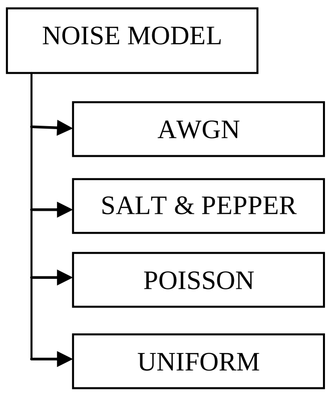

Fig. 1. Noise Model

A. Additive white Gaussian Noise:

The sources of Gaussian noise in digital images are poor illumination and high temperature of sensor during acquisition process. this noise is distributed over the image pixels[10]. the PDF of Gaussian noise is bell shape. this noise is added with the pixel of the original image. The PDF is given by,

$$\mathrm{P(z)} = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(z-\mu)^2}{2\sigma^2}} \qquad (3)$$

Fig. 2. Image containing with additive white Gaussian noise

B. Salt and Pepper Noise:

The salt and pepper noise is also called as impulse noise or shot noise. the sources of salt and pepper noise is error in transmission process and faulty memory locations[6]. In this noise there are two possible values are a and b and the probability of eachis less than 0.1.For 8 bit image 255 values for salt noise and 0 values for pepper noise. The PDF is given by,

$$p(Z) = \begin{cases} p_a & for\ z = a \\ p_b & for\ z = b \\ 0 & otherwise \end{cases} \qquad (4)$$

Fig. 3. Image containing with Salt & pepper noise

C. Poisson Noise:

The sources of Poisson noise is camera sensor. this noise has root mean square value proportional to square root intensity of image [6]. In this noise different noise pixels has independent noise values. The PDF is given by ,

Fig. 4. Image containing with Poisson noise

$$p(x) = \frac{e^{-x}\lambda^x}{x!}\ for\ \lambda > 0\ and\ x = 0,1,2 \ldots. \qquad (5)$$

D. Uniform Noise:

The sources of uniform noise is during digitization process of image. It is also known as quantization noise. This noise used for generate different types of noise distribution. This noise provides unbiased noise. the PDF is given by,

$$p(Z) = \begin{cases} \frac{1}{b-a}, if\ a \le z \le b \\ 0 \quad otherwise \end{cases} \qquad (6)$$

Fig. 5. Image containing with Uniform noise

III. *Image Denoising Techniques*

There are many denoising techniques to remove noise from the image there are spatial domain techniques and transform domain techniques in this paper reviews spatial domain filtering.

A. Spatial domain filtering:

Spatial domain filtering techniques classified shown in figure

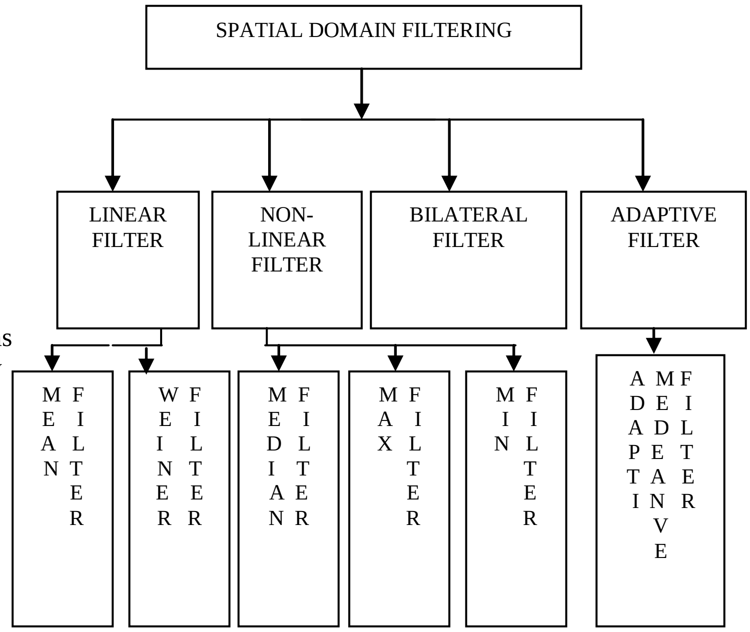

Fig. 6. Classification of Spatial Filters

B. Linear filters:

Linear filters are used to remove some type of noise. Mean filter and Gaussian filter types of linear filters. These filters remove the noise but tend to blur the edges and lost details of image. these filter are easy to implement.

a) Mean filter:

This is simple linear averaging spatial filter. It replaces the center pixel value by averaging neighborhood of center pixel including center pixel itself [5]. It use filter mask are 3x3, 5x5, 7x7 depending upon noise value.

Merits:

- Easy to implement

Used to remove the impulse noise.
Demerits:

- It does not preserve details of image.
- Some details are removes of image with using the mean filter.

b) Weiner filter

Weiner filter is linear filter. they remove noise from the degraded image. the Weiner filter reduced mean square error as much possible [1]. it preserve edges but blur the image. this is suitable for salt and pepper and Gaussian noise.

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C. Non-linear filters:

There are different types of non-linear filter developed like median filter ,weighted median filter , max filter to overcome the disadvantages of linear filters

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a) Median filter:

Median Filter is a simple and non-linear filter. It is easy to implement method of smoothing images. Median filter is used for reducing the value of intensity variation between one pixel and the other pixel [1]. In this filter, we replaces center pixel by the median value of neighboring pixel of image including center pixel. The median filter gives best result when the impulse noise percentage is less than 0.1 %. When the quantity of impulse noise is increased the median filter not gives best result.

Steps of Median Filter:

- Step 1. Select a two dimensional mask of size 3*3.
- Step 2.Compute the median of the pixel values in mask.
- Step 3. Replace center pixel with by median value
- Step 4. Repeat steps 1 to 3 until all the pixels in the image are processed.

Advantage:

- It is easy to implement.
- Used for removing different types of noises.

Disadvantage:

- Median Filter tends to remove image details likes lines and corners ,while noise removing.

b)Max filter:

It is non-linear spatial filter. It replaces the value of pixel by maximum value of intensity of neighborhood of that pixel [4]. this filter finds maximum brightness points in image.It removes pepper noise.

c) Min Filter:

It is Non-linear spatial filter.It replaces the value of pixel by minimum value of intensity of neighborhood of that pixel [4].this filter finds minimum brightness points in image.it removes salt noise.

D. Adaptive Filter:

Adaptive filters adapt their response depending on the characteristics of the image. The filter adapts based on the characteristics of the pixel intensities within the filter mask. Adaptive filters perform better than the non-adaptive filters in terms of preserving the image details while removing the noise.

a) Adaptive Median Filter:

It performs well on images containing high density noise. It preserves the details of image while removing the noise. It changes window size depending of condition. first it calculates minimum , maximum and median value of window of corrupted image[4].In second stage it check median is noise or not. If the median is noise then increase the size of window and calculates the median proceeds to stage two. In stage two check the pixel is noise or not. if it is noise then replace the selected pixel with previously median otherwise pixel remains unchanged.

E. Bilateral filter:

Bilateral filter is non-linear weighted averaging filter. It is simple edge preserving filter.[2][7] it is combination of two filters range filter and domain filter. domain filter weight set based on distance between two pixels and range filter weight set based on difference between intensity level of pixel

Merits:

- It is removing noise with preserving edges of image
- It is also preserves the fine details of image

Demerits:

- It is artifacts to gradient reversal.
- Bilateral Filter cannot remove salt & pepper noise

IV. PERFORMANCE MATRICES

A. Mean Square Error:

The mean square error is defined between original image and reconstructed image is defined by,

$$\text{MSE}=\frac{1}{MN}\sum(f(x,y)-z(x,y))^2 \qquad (7)$$

where f(x,y) is original image and z(x,y) is reconstructed image. M is number of rows and N is number of columns. for lower value of MSE gives lower error in images. Maximum value of MSE is 100 and Minimum value of MSE is 0

B. Peak Signal to Noise Ratio:

The peak signal to noise ratio is defined between original image and reconstructed image is defined by,

$$\text{PSNR} = \log_{10}\frac{255^2}{MSE} \qquad (8)$$

Peak signal to noise ratio decide quality of image. for higher peak signal to noise ratio gives better quality of images. Maximum value of PSNR is 99.

V. RESULTS & IMPLEMENTATION

All the Experiments carried out on standard images which size is 256 x 256 which are png format shown in figure. simulation is performed using Matlab R2013a software.

(a) (b)

Fig. 7.(a) Barbara Image (b) Montage Image

The input images are degraded by a Gaussian white noise with zero mean and 0.06 variance, Salt & pepper noise with noise density 0.1,Uniform noise which interval is [0,1] and Poisson noise which interval is [0,1].For Removing noise various spatial linear filters which are Weiner filter ,Mean filter and various spatial non-linear filters which are median filter, max filter, min filter and adaptive filter are adaptive median filter and bilateral filter have been used.

The Performance of the spatial filters is evaluated by Peak signal to noise ratio and Mean square error.

Table 1 in the Appendix A shows performances of Spatial filters removing different types of noise in Barbara image in terms of psnr and mse. Similarly Table 2 corresponds to montage image. Figure 8 shows the image degraded by different noise and noisy image filtered using various filters. Similarly Figure 9 corresponds to Montage Image.

VI. CONCLUSION

In this paper we discussed various noise model and filtering techniques like linear filtering, non-linear filtering , adaptive filtering and bilateral filtering techniques and also observed the different techniques for different noise model. we show that bilateral filter gives better result for Poisson noise and Gaussian noise. we observed the quality of image using psnr and mse and concluded that the bilateral filter and max filter gives better psnr value and mse value of restored image. we also show that the median filter remove salt & pepper noise and uniform noise.

VII. FUTURE SCOPE

This analytical study further extended by increasing number of noise model and increasing number of filtering techniques . we remove noise using transform domain filtering techniques and also removing noise using hybrid approach. we can remove noise using hybrid approach by involving two or three filter and enhance the quality of image.

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APPENDIX A

Table I. Performance comparison of various filters on different types of noise using Barbara Image

Type of Noise	PSNR						
	Linear Filters		Non Linear Filters			Adaptive Filters	Bilateral Filter
	Mean Filter	Weiner Filter	Median Filter	Max Filter	Min Filter	Adaptive Median Filter	Bilateral Filter
Gaussian noise	29.28	29.15	28.54	52.42	24.10	28.14	62.23
Salt & Pepper noise	29.27	29.38	33.46	58.41	25.15	37.84	56.44
Poisson noise	32.50	33.76	32.52	52.24	25.21	32.51	80.29
Uniform noise	32.76	34.75	34.20	69.96	27.41	39.63	72.47
Type of Noise	MSE						
	Linear Filters		Non Linear Filters			Adaptive Filters	Bilateral Filter
	Mean Filter	Weiner Filter	Median Filter	Max Filter	Min Filter	Adaptive Median Filter	Bilateral Filter
Gaussian noise	76.71	79.04	90.87	0.3723	252.49	99.61	0.0389
Salt & Pepper noise	76.90	74.93	29.27	0.0937	198.524	10.68	0.1475
Poisson noise	36.50	27.34	36.36	0.387	195.91	36.42	0.00060
Uniform noise	34.36	21..77	24.66	0.0066	117.99	7.07	0.0037

Table II. Performance comparison of various filters on different types of noise using Montage Image

Type of Noise	PSNR						
	Linear Filters		Non Linear Filters			Adaptive Filters	Bilateral Filter
	Mean Filter	Weiner Filter	Median Filter	Max Filter	Min Filter	Adaptive Median Filter	Bilateral Filter
Gaussian noise	30.17	30.05	28.64	55.27	24.15	28.39	62.75
Salt & Pepper noise	31.49	32.10	39.66	69.58	27.22	44.49	72.62
Poisson noise	35.05	36.48	35.63	59.97	26.13	34.22	84.79
Uniform noise	35.72	38.86	40.51	88.51	30.53	45.24	71.42
Type of Noise	MSE						
	Linear Filters		Non Linear Filters			Adaptive Filters	Bilateral Filter
	Mean Filter	Weiner Filter	Median Filter	Max Filter	Min Filter	Adaptive Median Filter	Bilateral Filter
Gaussian noise	62.49	64.19	88.92	0.1930	249.94	94.12	0.0344
Salt & Pepper noise	96.07	40.05	7.02	0.0072	123.11	2.3099	0.0036
Poisson noise	20.28	14.61	17.78	0.0654	158.214	24.55	0.00024
Uniform noise	17.39	8.43	5.38	0.00009	57.49	1.94	0.0047

Fig. 8. Barbara image containing various types of noise and filtered by different spatial filters

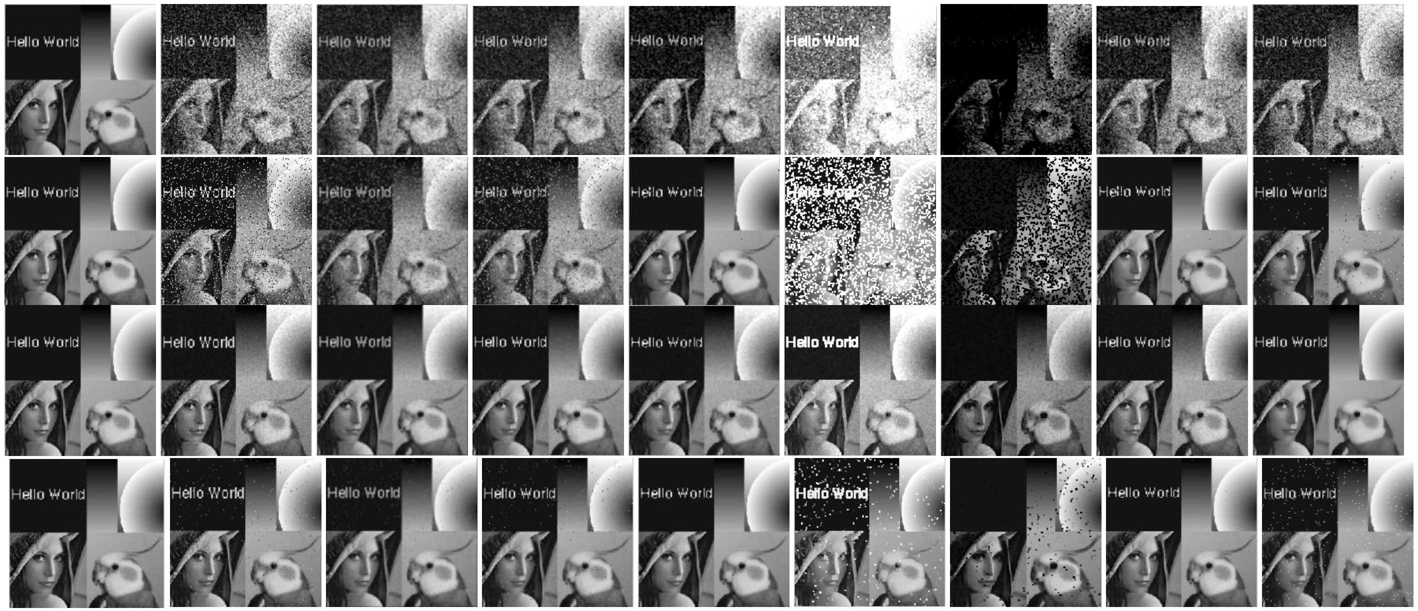

Fig. 9. Barbara image containing various types of noise and filtered by different spatial domain filter