International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 5 Issue 7, July-2016

Comparative Study of Digital Image Restoration performance Using Filters

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ABSTRACT: In this paper, a method to restore the image degraded by white noise has been introduced. This method uses different filters to regain restore the quality of degraded image. The median filter is one of the well-established linear filtering methods and is well known for its excellent performance in denoising the white noise. However the estimation of the original image from the degraded image characterization is very difficult task as in most of time only a degraded version of image in available in many image processing application. Performance comparison of the de-noising methods as Average filter, Gaussian filter, Median filter, Wiener filter in frequency domain. Wiener filter in frequency domain have the lowest value of PSNR with the Gaussian noise and average filter have the highest PSNR value. Again performance comparison of the de-noising methods as Average filter, Gaussian filter, Median filter, Wiener filter in frequency domain (in PSNR). Median filter have the highest value of PSNR with the salt & pepper noise.

It has been observed that the median filter is having overall performance for images corrupted by white noise better compared to other nonlinear filters. Thus, the median filter is a solution to the restoration problem based upon the use of linear filter.

Keywords: PSNR, MSE.

1 INTRODUCTION

We may define noise to be any degradation in the image signals, caused by external disturbance. If an image signal is being sent electronically from one place to another place, via satellite or wireless transmission, or through the networked cable, we may be expect errors to occur in the image signals. These errors will appear on the image output in different ways depending on the type of disturbance in the signal. We know what types of error to expected, and hence the type of noise/echo on the image; hence we can choose the most appropriate method for reducing the effects. Cleaning an images corrupted by noise/echo signal is thus an important area of image restoration. [2]
The main Applications are: Medicine, Agriculture, Industry, Law enforcement and Digital camera images. In this paper we have made a comparison of various filters for de-noising any image.

II THEORETICAL DEVELOPMENT

Spatial Filtering

Intuitively, spatial resolution can be measure as the smallest discernible detail in an image. Quantitatively, the spatial resolution can be stated in a different number of ways, with line pairs per unit distance, and dots (pixels) per unit distance being among the most common measures [3,4]. An image can be modified by applying a particular function to each pixel value. In spatial filtering apply a function to a neighborhood of each pixel. The main idea is to move a “mask /kernel”: a rectangle (usually with sides of odd length) or other shape over the given image. As we do this, we create a new image whose pixels have grey values calculated from the grey values under the mask/kernel, shown in figure 1 Mask/Kernel for average is given by Matlab command :

```
>> H=ones (3,3)/9
```

$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$
$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$
$\frac{1}{9}$	$\frac{1}{9}$	$\frac{1}{9}$

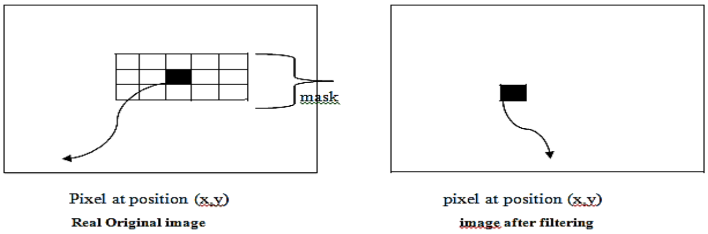


Figure 1: using a spatial mask (3x5) on an image

The combination of mask and function is called a filtering. If the function by which the new grey value is calculated is a linear function of all the grey values in the mask, then the filter is called a linear filter[1],[10][12].
We can implement a linear filter by multiplying all elements in the mask by corresponding elements in the neighborhoods, and all these products are adding up.
Suppose that the mask values are given by:-

m(-1,-2)	m(-1,-1)	m(-1,0)	m(-1,1)	m(-1,2)
m(0,-2)	m(0,-1)	m(0,0)	m(0,1)	m(0,2)
m(1,-2)	m(1,-1)	m(1,0)	m(1,1)	m(1,2)

Figure 2 matrixes of mask values

Corresponding pixel values are

p(i-1, j-2)	p(i-1, j-1)	p(i-1, j)	p(i-1, j+1)	p(i-1, j+2)
p(i, j-2)	p(i, j-1)	p(i, j)	p(i, j+1)	p(i, j+2)
p(i+1, j-2)	p(i+1, j-1)	p(i+1, j)	p(i+1, j+1)	p(i+1, j+2)

Figure 3 Matrix of image pixels

We now multiply and add:

$$\sum_{S=-1}^{1}\sum_{T=-2}^{2} m(s,t)\,p(i+s,\,j+t)$$

We see that spatial filtering requires three steps:
1. The mask positioned over the current pixel,
2. Form all products of the filter elements with the corresponding elements of the neighborhood,
3. Add up all the products.

This process must be repeated for every pixel in the image.

Edges of the image

There is an obvious problem in applying a filter--what happens at the edge of the image, where the mask partly falls outside the image? Such a case is illustrated in figure 5.4. There will be a lack of grey values to use in the filter function.

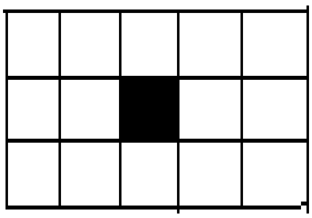


Figure 4: A mask at the edge of an image

Different ways to dealing with this problem are:

1. Ignore the edges. That is, we only apply the mask to those pixels in the image for with the mask will lie fully within the image. This means all pixels except for the edges, and results in an output image which is smaller than the original. If the mask is very large, we may lose a significant amount of information by this method.
2. Padding with zeros. We assume that all necessary values outside the image are zero. This provides all values to work with, and will return an output image of the same size as the original, but introducing unwanted artifacts (for example, edges) around the image.

Mean / Average Filter

If the Gaussian noise has mean 0, then we would expect that an average filter would average the noise to 0. The larger size of the filter mask, the closer to zero. Unfortunately, averaging tends to blur an image. However, if we are preparing to trade off blurring for noise reduction, then we can reduce noise significantly by this method[6,7,8].

Gaussian Filter

Gaussian filters are a class of low-pass filters; all based on the Gaussian probability distribution Function .it uses a different kernel that represents the shape of a Gaussian (`bell-shaped') hump

$$G(x) = \frac{1}{\sqrt{2\Pi\sigma}} e^{\left(-\frac{x^2}{2\sigma^2}\right)}$$

Gaussian function in one dimensional
σ = standard deviation
Matlab code for 1-D graph

```
>> s=1;
>> n=100;
>> x=-1/2:1/(n-1):1/2;
>> f=exp(-(x.^2)/(2*s^2));
>> f=f/sum(sum(f));
>>plot(x,f);
```

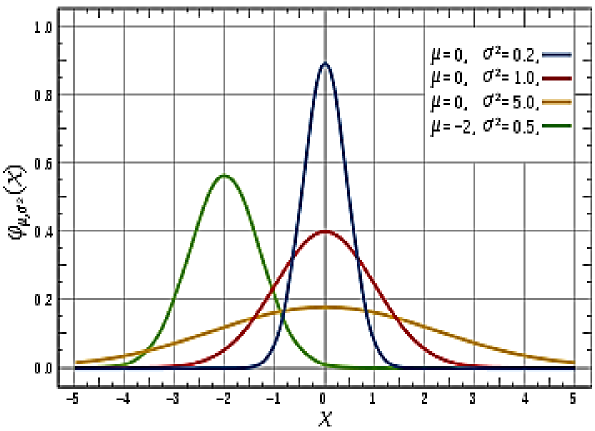


Figure 5: Gaussian distribution function

Noise Reduction using convolution with a Gaussian smoothing kernel

Gaussian function in two- dimensional.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$

```
>>s=1;
>>n=100;
>> x=-1/2:1/(n-1):1/2;
>> [y,x]=meshgrid(x,x);
>> f=exp(-((x.^2)+(y.^2))/(2*s^2));
>> f=f/sum(sum(f));
>> plot3(x,y,f);
```

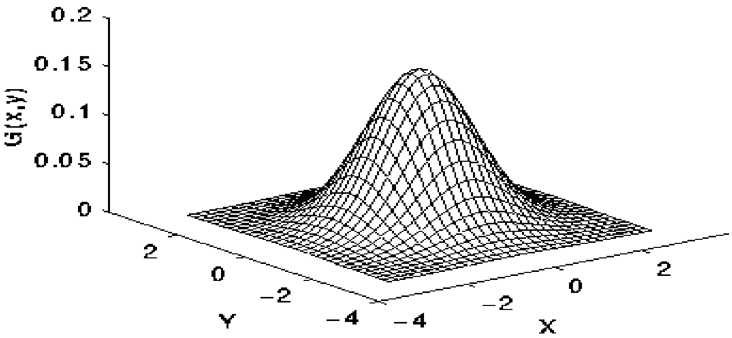


Figure 6: Two dimensional Gaussian

Median Filter

Median filtering seems almost tailor-made for removal of noise. Recall that the median of a set is the middle value when they are sorted. When there are even numbers of values, then the median is the mean of the middle two[9,13]. A median filter is an example of a non-linear spatial filter; using a 3x3 mask, the output value is the median of the values in the mask.

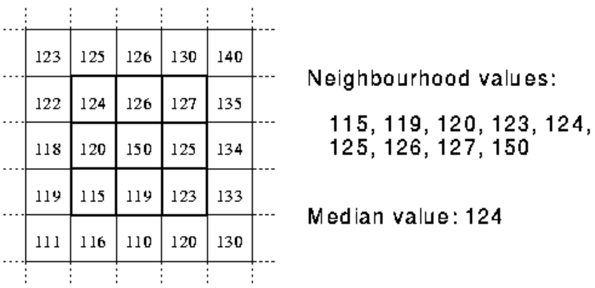


Figure 7: Neighborhood values of images and it median

We see that very large or very small values -- noisy values-- will end up at the top or bottom of the sorted list. Thus the median will replace a noisy value with one closer to its surroundings.

III. SIMULATION RESULTS

We performed extensive simulations in MATLAB® in order to evaluate performance of various filters and also we have made effects of filters for various masking of the images. In last we have made comparison among various techniques also.

Average Filter Results:

Figure 8 shows original image on which the Gaussian noise is applied as shown in fig.9.

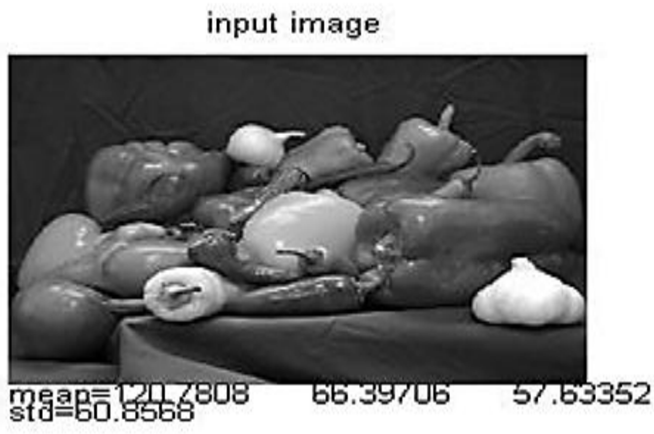


Fig. 8: Original Image

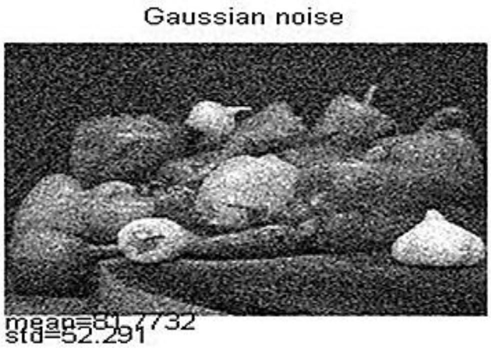


Fig. 9: noised image

Figure 10, fig.11, fig.12 and fig.13 show the effect of masking on the average filter. Table 1 shows the MSE and PSNR values for various masking and graph 1 shows the results of average filter.

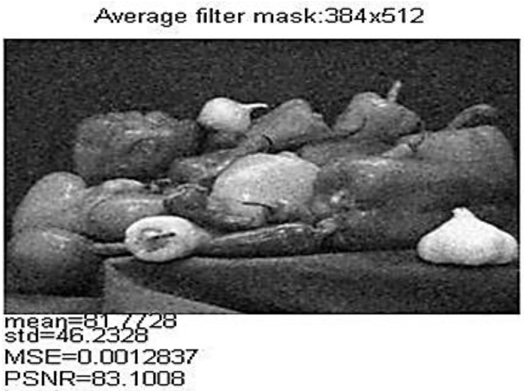
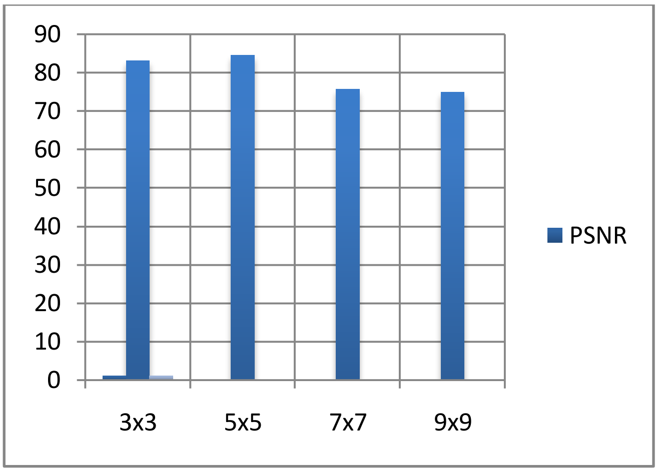


Fig.10: Filtering mask 3x3

Fig.11: Filtering mask 5x5

Fig.12 Filtering mask 7x7

Fig. 13 Filtering mask 9x9



Gaussian Filter:

Figure 14 shows original image on which the Gaussian noise is applied as shown in fig.15.

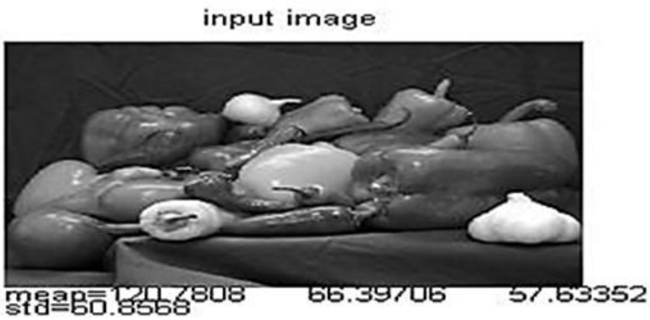


Fig.14 Original image

Table 1 : Comparison of various masking for average filter

S.No	Average Filter	MSE	PSNR
1	3x3 mask	0.0012837	83.1008
2	5x5 mask	0.00093535	84.4757
3	7x7 mask	0.0070869	75.6808
4	9x9 mask	0.0084112	74.9368

Fig. 15 noised image

Figure 16, fig.17, fig.18 and fig.19 show the effect of masking on the average filter. Table 2 shows the MSE and PSNR values for various masking and graph 2 shows the results of average filter.

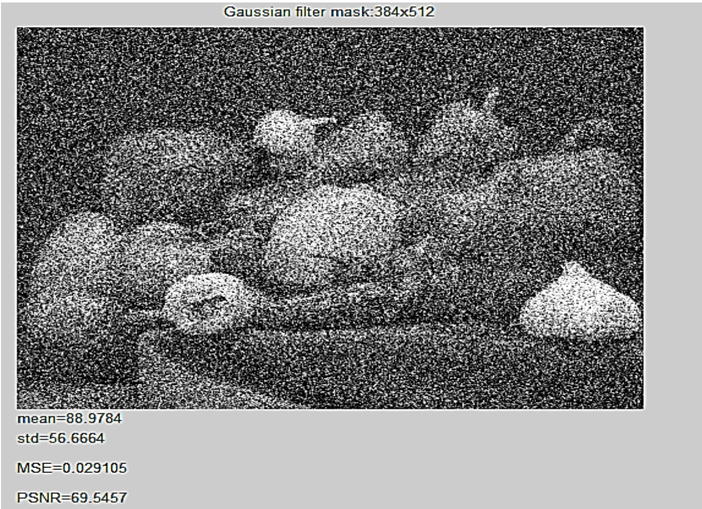


Fig. 16 filtering 3x3

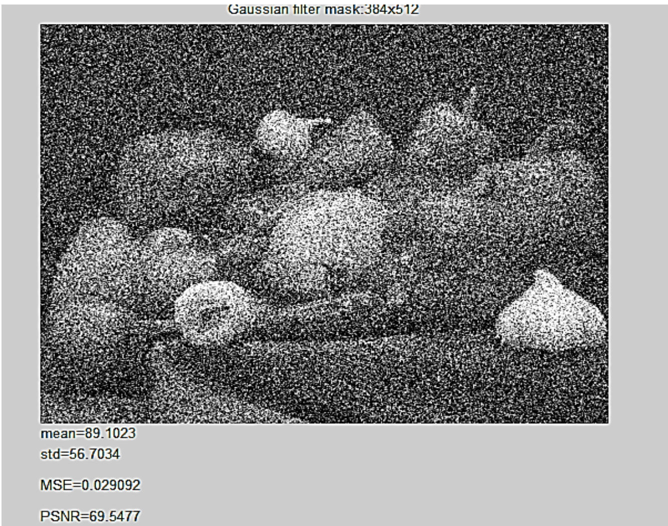


Fig.17 filtering 5x5

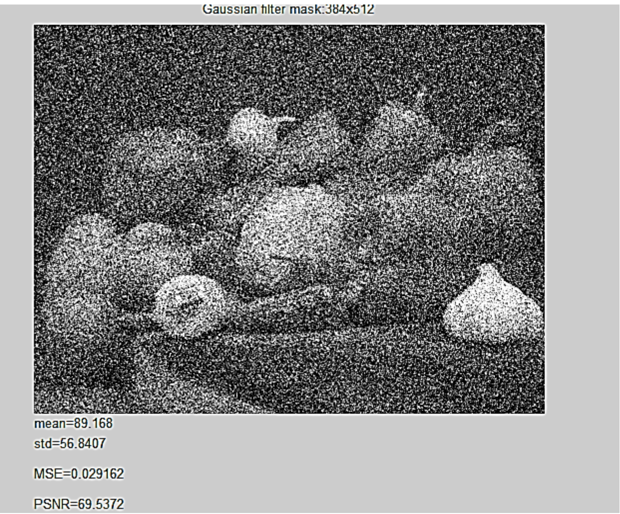


Fig. 18 filtering7x7

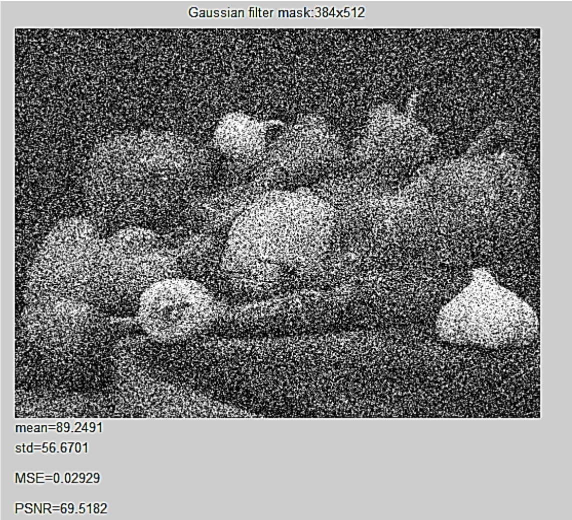


Fig. 19 filtering 9x9

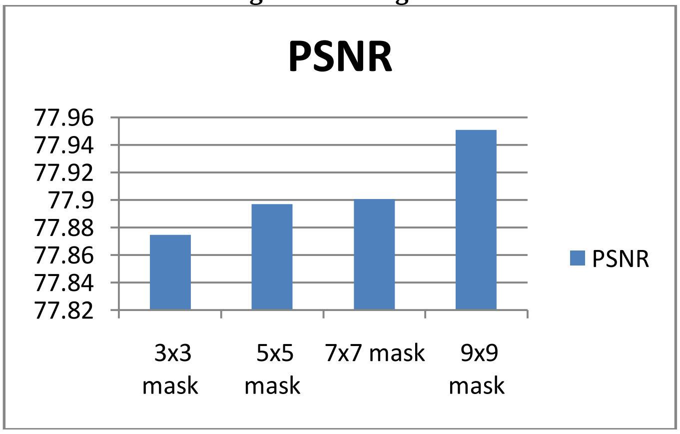


Table 2 Comparison of Gaussian filter with different masking

S.No	Gaussian Filter	MSE	PSNR
1	3x3 mask	0.0042761	77.8749
2	5x5 mask	0.0042544	77.897
3	7x7 mask	0.0004251	77.9005
		0.0042021	77.9507

Median Filter:

Figure 20 shows original image on which the Gaussian noise is applied as shown in fig.21.

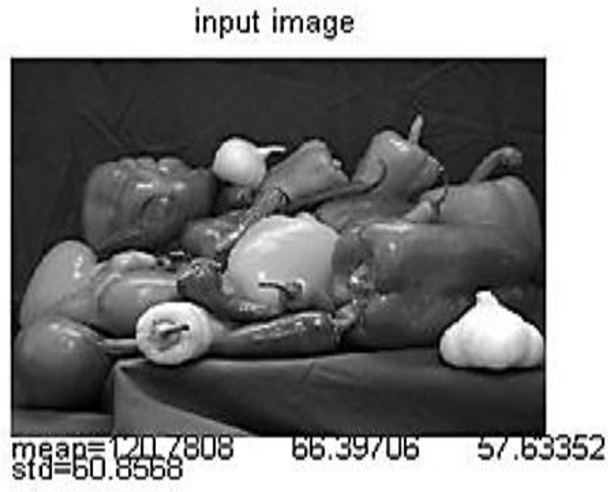


Fig. 20 Original image

Fig. 21 noised image

Figure 22, fig.23, fig.24 and fig.25 show the effect of masking on the average filter. Table 3 shows the MSE and PSNR values for various masking and graph 3 shows the results of average filter.

Fig. 22 filtering 3x3

Fig. 23 filtering 5x5

Fig. 24 filtering 7x7

Fig. 25 filtering 9x9

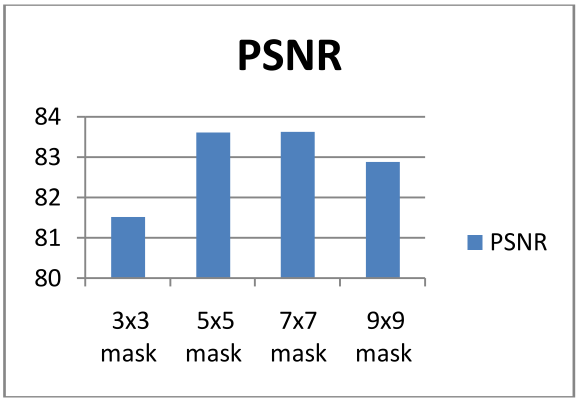


Table 3 comparision of median filter PSNR

S.No	Filter's Name	MSE	PSNR
1	3x3 mask	0.0018501	81.5131
2	5x5 mask	0.0011429	83.6053
3	7x7 mask	0.0011383	83.6229
4	9x9 mask	0.0013512	82.8781

Table 4 Comparison of Various filters

S	Filter's Name	Mean	Std	MSE	PSNR
1	Average	81.7728	46.2328	0.0012837	83.1008
2	Gaussian	89.3459	56.9727	0.029425	69.4983
3	Median	81.4817	47.4352	0.0018641	81.4807

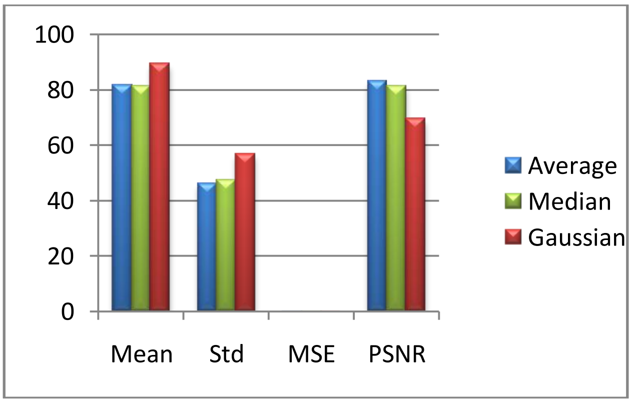


Table 4 shows a performance comparison of the denoising methods as Average filter, Gaussian filter, Median filter, Wiener filter in frequency domain.

CONCLUSION

For this specific comparison, the median filter is better noise immunity and generates a lower error than any of the other procedures that are examined here. An image is degraded by white noise; the median filter is more suitable for restoration than a variety of smoothing filters such as the Gaussian, wiener, and mean/average. In an ideal case where both the original and noise images are known, it has been found that the median filter is more effective. This comparison can be seen in table and filtered image.

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