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# A COMPARATIVE ANALYSIS OF IMAGE RESTORATION USING INVERSE,WEINER, MEDIAN, TRIMMED AVERAGE FILTERS

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**ABSTRACT**

*In image processing, an important step is removing noise from images, before processing of those images for further analysis is a great challenge for the researchers. Image denoising occurs due to transmission channel error, camera misfocus, atmospheric turbulence, relative object camera motion etc…Such degradations are unavoidable while a scene is captured through a camera. Restoration of such image is a extremely essential in many practical applications. Image denoising involves the manipulation of the image data to produce a visually high quality image. The kind of noise removal algorithms to remove the noise depends on the type of noise that occurs during transmission and capturing. To remove these types of noise we have many filters like mean filter, median filter, inverse filter, wiener filter, pseudo inverse filter, trimmed average filter. No single filter can remove both type of noise. Every filter has their own advantages and disadvantages so that some kind of filter use to remove some kind of noise based on the characteristic of the noise, if the noise is not completely removed by that filter again the partially removal noisy image is filtered by another filter such as hybrid filter (cascading of two or more filter) ,this hybrid filters can improve the signal power and reduce the noise power so that it can improve the probability of signal to noise ratio or improved signal to noise ratio, and how far it is restored to know that the proposed algorithm measures the normalized correlation also. In this algorithm various special types of noises applying to image and investigates the result of noise reduction techniques by applying the various filter.*

***Keywords: Denoising, Median Filter, Hybrid Filter, Inverse Filter, Pseudo Inverse Filter.***

## I. INTRODUCTION

Digital Image Processing is a component of digital signal processing. The area of digital image processing refers to dealing with digital images by means of a digital computer. Digital image processing has several advantages above analog image processing; it allows a considerably wider collection of algorithms to be applied to input data and can keep away from problems for instance the build-up of noise and signal deformation during processing. Digital Image Processing involves the modification of digital data for improving the image qualities with the aid of computer.

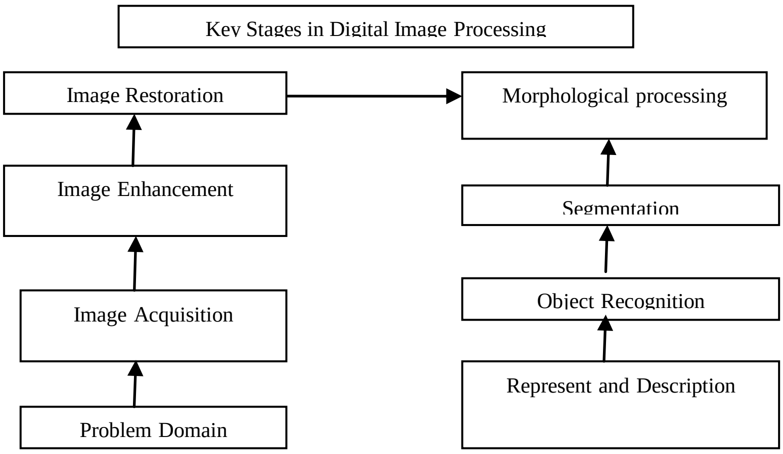


**Figure: 1 Key Stages in Digital Image Processing**

## II. IMAGE DEGRADATION MODEL

### 2.1 Simple Image Degradation and Restoration Process

For a linear invariant system, the observed/distorted image $i(x, y)$ can be modeled as a convolution of the object function $o(x, y)$, which is the actual object in the scene, with the image degradation function $h(x, y)$, which is also commonly known as the point spread function.

$$i(x, y) = o(x, y) * h(x, y) + n(x, y)$$

Where $n(x, y)$ is an additive noise function that describes the random variation of the pixel intensity

According to the convolution theorem, a convolution of two spatial functions can be expressed as product of their respective Fourier transform in frequency domain. Thus, the image degradation model can be written as

$$I(u, v) = O(u, v)H(u, v) + N(u, v)$$

In a simplest image degradation model, the degradation function is modeled as a low pass filter, which resulted in a blurry effect. Fig  shows the block diagram of image degradation and restoration process.[2] Fundamentally, the image restoration process involves in reversing the distortion effects.

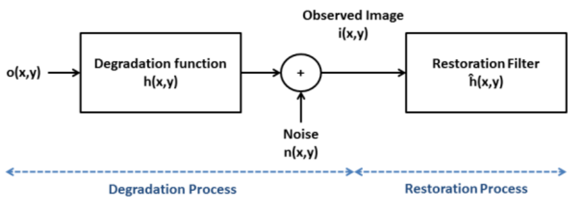


**Fig 2.1 Block Diagram of Image Degradation and Restoration Process**

### 2.2 Degradation/Point Spread Function Estimation

The usual assumptions of the degradation function are:

1. Linearity, and
2. Position-invariant, i.e., the response at any point in the image depends only on the value of  the input at that point, not on its position.

For a finite camera aperture size, the impulse response of the camera can be described by the airy function, which is shown in Fig.2.2. One can see that when a point object is imaged by the imaging system, the observed image is affected by the point spread function of the imaging system. Fig.2.3.shows the degraded image which is caused by the point spread function..

**Fig 2.2 Point Spread Function (Airy Disk Pattern) of a point source**

## III. NOISE MODEL

Various Causes of Noise in Images

Noise is introduced in the image at the time of image acquisition or transmission. Different factors may be responsible for introduction of noise in the image. The number of pixels corrupted in the image will decide the quantification of the noise[3].

The principal sources of noise in the digital image are:

a) The imaging sensor may be affected by environmental conditions during image acquisition.

b) Insufficient light levels and sensor temperature may introduce the noise in the image.

c) Interference in the transmission channel may also corrupt the image.

d) If dust particles are present on the scanner screen, they can also introduce noise in the image.

Since main sources of noise presented in digital images are resulted from atmospheric disturbance and image sensor circuitry, following assumptions can be made:

- The noise model is spatial invariant, i.e., independent of spatial location.
- The noise model is uncorrelated with the object function.

Some commonly used noise models can be categorized into two groups: additive and Multiplicative noise.

### 3.1 Additive and Multiplicative Noise

In this chapter, we discuss noise commonly present in an image. Note that noise is undesired information that contaminates the image. In the image denoising process, information about the type of noise present in the original image plays a significant role. Typical images are corrupted with noise modeled with either a Gaussian, uniform, or salt or pepper distribution. Another typical noise is a speckle noise, which is multiplicative in nature.

Noise is present in an image either in an additive or multiplicative form. An additive noise follows the rule

$$w(x, y) = s(x, y) + n(x, y)$$

While the multiplicative noise satisfies

$$w(x, y) = s(x, y) \times n(x, y),$$

Where s(x,y) is the original signal, n(x,y) denotes the noise introduced into the signal to produce the corrupted image w(x,y), and (x,y) represents the pixel location.

The above image algebra is done at pixel level. Image addition also finds applications in image morphing. By image multiplication, we mean the brightness of the image is varied.

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The digital image acquisition process converts an optical image into a continuous electrical signal that is, then, sampled. At every step in the process there are fluctuations caused by natural phenomena, adding a random value to the exact brightness value for a given pixel.

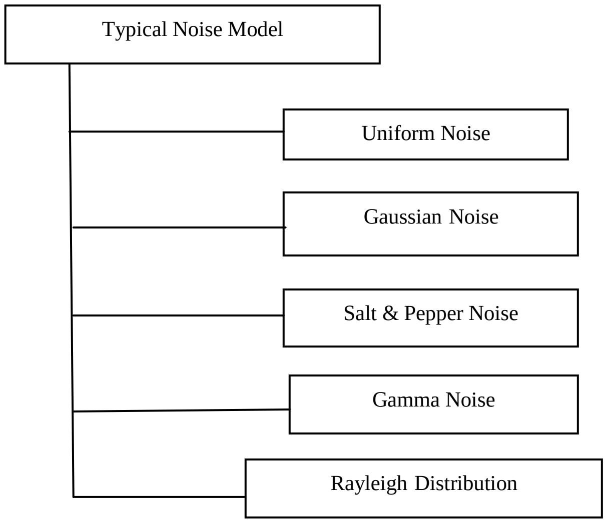


**Fig: 3.1Typical Noise Model**

### 3.2 Additive Noise Models

In this case, the noise is superimposed upon the image, which resulted in variation of the image signal. Some common noise distributions are[6]:

- Gaussian noise distribution

$$p(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{(z-\mu)^2}{2\sigma^2}}$$

- Rayleigh noise distribution

$$p(z) = \frac{2}{b}(z-a)e^{-\frac{(z-a)^2}{b}}, \quad \text{for } z \geq a$$

- Gamma(a,b) noise distribution

$$p(z) = \frac{a^b z^{b-1}}{(b-a)!} e^{-az}, \quad \text{for } z \geq 0$$

- Exponential noise distribution

$$p(z) = ae^{-az}, \quad \text{for } z \geq 0$$

## IV. DENOISING ALGORITHMS USING FILTERING TECHNIQUES

Filtering in an image processing is a basis function that is used to achieve many tasks such as noise reduction, interpolation, and re-sampling. Filtering image data is a standard process used in almost all image processing systems. The choice of filter is determined by the nature of the task performed by filter and behavior and type of the data. Filters are used to remove noise from digital image while keeping the details of image preserved is a necessary part of image processing. Filters can be described by different categories:--

1. Filtering without Detection

In this filtering there is a window mask which is moved across the observed image. This mask is usually of the size (2N+1)/2, in which N is a any positive integer. In this the centre element is the pixel of concern. When the mask is start moving from left top corner to the right bottom corner of the image, it perform some arithmetic operations without discriminating any pixel of image

2. Detection followed by Filtering

This filtering involves two steps. In the first step it identify the noisy pixels of image and in second step it filters those pixels of image which contain noise. In this filtering also there is a mask which is moved across the image. It performs some arithmetic operations to detect the noisy pixels of image. Then the filtering operation is performed only on those pixels of image which are found to be noisy in the first step, keeping the non-noisy pixel of image intact.

V.IMAGE BLURRING AND RESTORATION OPERATION

The image restoration process can be achieved by inversing the image degradation process, i.e.,

$$\hat{O}(u,v) = \frac{I(u,v) - N(u,v)}{H(u,v)} = \frac{I(u,v)}{\hat{H}(u,v)}$$

Where $1/\hat{H}(u,v)$the inverse is filter, and $\hat{O}(u,v)$ is the recovered image.

Although the concept is relatively simple, the actual implementation is difficult to achieve, as one requires prior knowledge or identifications of the unknown degradation function $h(x,y)$ and the unknown noise source $n(x,y)$.

In the following sections, common noise models and method of estimating the degradation function are presented.

### 4.1 Mean Filter

The mean filter is a simple spatial filter .It is a sliding-window filter that replaces the center value in the window. It replaces with the average mean of all the pixel values in the kernel or window. The window is usually square but it can be of any shape.

| Unfiltered Values | | |
|---|---|---|
| 8 | 4 | 7 |
| 2 | 1 | 9 |
| 5 | 3 | 6 |

**Fig 4.1 An Example of mean filtering of a 3x3 kernel of values**

**Advantage:**

a. Easy to implement

b. Used to remove the impulse noise.

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

### 4.2 Restoration- Median Filter

Median Filter is a simple and powerful non-linear filter which is based order statistics. It is easy to implement method of smoothing images. Median filter is used for reducing the amount of intensity variation between one pixel and the other pixel. In this filter, we do not replace the pixel value of image with the mean of all

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neighboring pixel values, we replaces it with the median value. If the neighboring pixel of image which is to be considered contains an even numbers of pixels, than the average of the two middle pixel values is used to replace. 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.

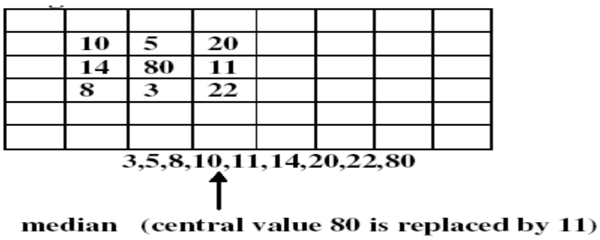


**Figure 5.1 Method of Median Filter**

### 4.3 Algorithm of Median Filter

The algorithm for the median filter is as follows:

Step 1. Select a two dimensional window W of size 3*3. Assume hat the pixel being processed is Cx,y.

Step 2. Compute Wmed the median of the pixel values in window W.

Step 3. Replace Cx,y by Wmed.

Step 4. Repeat steps 1 to 3 until all the pixels in the entire image are processed.

**Advantage:**

a. It is easy to implement.

b. Used for de-noising different types of noises.

**Disadvantage:**

a. Median Filter tends to remove image details while reducing noise such as thin lines and corners[7].

b. Median filtering performance is not satisfactory in case of signal dependant noise. To remove these difficulties

different variations of median filters have been developed for the better results.

1) C.Restoration – Inverse Filter

As shown in the previous chapter, the image restoration can be achieved by applied an inverse filter $1/\hat{H}(u,v)$ to the observed blurry image, i.e.,

$$\hat{O}(u,v) = \frac{I(u,v)}{\hat{H}(u,v)}$$

Theoretically, the inverse filter is the inverse of the degradation function. However, if this was implemented, the inverse filter will enlarge the high frequency noise. This is due to that most degradation function have low-pass filter nature, hence, it has relatively low high frequency power spectrum. If an inverse operation is performed, the inverse filter will have a high-pass filter nature, which will cause the blurred image to have a magnified high frequency noise.

Therefore, the actual implementation of inverse filter will need to consider the nature of the degradation function and blurred image function, i.e.,

$$\hat{H}(u,v) = \begin{cases} \frac{1}{H(u,v)}, & |H(u,v)| \geq \alpha \\ 0, & |H(u,v)| < \alpha \end{cases}$$

where $\alpha$ is a threshold that is used to mitigate the effect of zeros in the degradation function.

2)D. Restoration – Wiener Filter

The effect of noise distribution has not been considered in the inverse filter operation. Let the additive noise power spectrum be $S_{nn}(u,v)$ and image power spectrum be $S_{xx}(u,v)$. Generally, $S_{nn}(u,v)$ has a dominant effect over $S_{xx}(u,v)$ in the high frequency region, as $S_{xx}(u,v)$ tends to concentrated in low frequency spectrum[8].

In the Fourier domain, the Wiener filter is expressed as

$$W(u,v) = \frac{H^*(u,v)}{|H(u,v)|^2 + S_{nx}(u,v)}$$

where $S_{nx}(u,v) = S_{nn}(u,v)/S_{xx}(u,v)$ is the noise-to-signal ratio. One can see that in high frequency region, the resulting $S_{nx}(u,v)$ will be relatively large, i.e., $S_{nx}(u,v) \gg |H(u,v)|$. Consequently, the high frequency response of the restoration filter is suppressed.

Figure 4.3 shows the power spectrum characteristics of the inverse filter and Wiener filter.

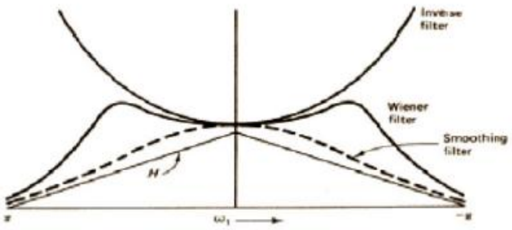


**Fig 5.2 Comparison Between Inverse Filter and Wiener Filter**

It is worth noting that if no noise is presented, i.e., $S_{nn}(u,v) \to 0$, the Wiener filter is the inverse filter:

$$W(u,v)|_{S_{nn}(u,v)\to 0} = \begin{cases} \frac{1}{H(u,v)}, & H(u,v) \neq 0 \\ 0, & H(u,v) = 0 \end{cases}$$

### 4.4 Restoration-Pseudo Inverse Filters

Suppose we have a known image function f(x , y) and a blurring function h(x , y), so we need to recover f(x , y) from the convolution

$$g(x,y) = f(x,y) * h(x,y)$$

$$G(u,v) = F(u,v) \; x \; H(u,v)$$

$$G(u,v)/H(u,v) = \{F(u,v) \; x \; H(u,v)\}/H(u,v)$$

Written as:

$$G(u,v)/H(u,v) = F(u,v)$$

## V. RESULTS

A Test image is taken and it is subjected to point spread function to degrade the image .after wards the adaptive linear filters applied to degraded image to get the restored image .To evaluate the fidelity criteria NCC and PSNR &ISNR is computed. In this computation the regression analysis will give a better idea which method is better one to calculate the efficiency of the algorithm.

Objectative fidelity criteria: For comparing original image and restored image, we calculate the parameters[2]:

### 5.1 Mean Square Error

The MSE is the cumulative square error between the restored image and original image defined by

$$MSE = \frac{1}{M \times N}\sum_{X=1}^{M}\sum_{Y=1}^{N}[f(x,y) - g(x,y)]^2$$

Where, f is the original image and g is the restored image. The dimension of the image is $M \times N$. Thus MSE should be as low as possible for effective denoising.

### 5.2 Peak Signal to Noise Ratio (PSNR)

PSNR is the ratio between maximum possible power of a signal and the power of distorting noise which affects the quality of its representation. It is defined:

$$PSNR = 10\, log_{10} \frac{255 \times 255}{\frac{1}{M \times N}\sum_{X=1}^{M}\sum_{Y=1}^{N}[f(x,y) - g(x,y)]^2} dB$$

Where **255($MAX_f$ )** is the maximum signal value that exists in our original “known to be good” image. Signal to noise ratio is defined as the power ratio between a signal and the background noise.

$$SNR = \frac{P_{signal}}{P_{noise}}$$

Where p is average power .both noise and power must be measured at the same bandwidth.

### 5.3 Normalized Correlation Coefficient (NCC)

$$NCC = \frac{1}{M \times N}\sum_{I=1}^{M}\sum_{J=1}^{N} f(I,J) \times g(I,J)$$

Where f(i,j) is the original image and g(i,j) is the restored image . This correlation measures the similarity between the original image and restored image

### 5.4 Improvement in Signal to Noise Ratio (ISNR)

Improvement in signal to noise ratio is used to test the performance of the image –restoration algorithm objectively. If f(x,y) and g(x,y) represent the original and the degraded image ,the expression of ISNR is given by.

$$ISNR = 10\log_{10}\frac{\sum_{x,y}[f(x,y) - g(x,y)]^2}{\sum_{x,y}[f(x,y) - h(x,y)]^2}$$

Here, h(x,y) is the restored image .This metric can be used for simulation purposes only because the original image is assumed to be available which is not true practically.

**Table 6.1 Result of Various Noise Removals with Trimmed Average Filter**

| TRIMMED AVERAGE FILTER | | | |
|---|---|---|---|
| NOISE | RMSE | PSNR | ISNR |
| GAUSSIAN | 12.1628 | 26.4301 | 0.0998 |
| POISSON | 7.3758 | 3.7746 | 0.016 |
| SALT&PEPPER | 15.5547 | 24.2936 | 0.3951 |
| SPECKLE | 12.8259 | 25.9691 | 0.2037 |
| DITHER | 122.1728 | 6.39 | 1 |

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**Table 6.2 Result of Various Noise Removals with Wiener Filter**

| WIENER FILTER | | | |
|---|---|---|---|
| NOISE | RMSE | PSNR | ISNR |
| GAUSSIAN | 24.7565 | 20.257 | 8.45E+06S |
| POISSON | 10.1193 | 20.0278 | 4.50E+06 |
| SALT&PEPPER | 32.8737 | 17.7938 | 6.6512+008 |
| SPECKLE | 25.9368 | 19.8525 | 7.04E+07 |
| DITHER | 122.1774 | 6.391 | 5.32E+07 |

**Table6.3 Result of Various Noise Removals with Median Filter**

| MEDIAN FILTER | | | |
|---|---|---|---|
| NOISE | RMSE | PSNR | ISNR |
| GAUSSIAN | 10.7841 | 27.4751 | 9.38E-01 |
| POISSON | 4.6844 | 34.7177 | 8.29E-01 |
| SALT&PEPPER | 1.9949 | 42.1323 | 275.664 |
| SPECKLE | 14.2554 | 25.0512 | 1.77E+00 |
| DITHER | 122.1219 | 6.3949 | 1.00E+00 |

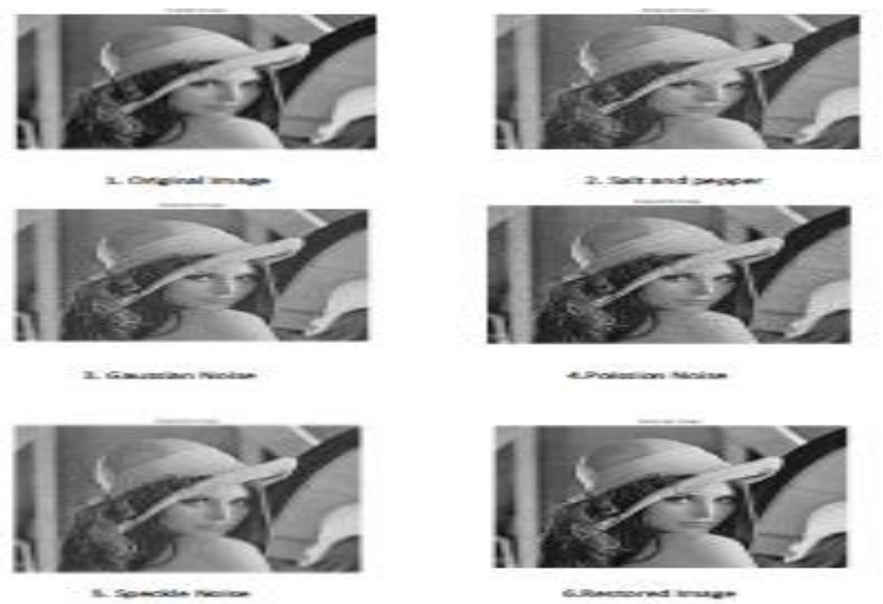

**Fig: 6.1 Restored & Noise Image's of Inverse Filter**

## VI. CONCLUSION

In modern digital world, the electronic industries are launching the electronic gadgets with better features day by day, by providing the better services and developing the next generation networks. To avoid the band width limitations in communications, digital communications such as digital image, video processing and multimedia processing are used. The selection of right denoising algorithm plays a vital role, it is important to experiment and compare the methods. In this paper, the computational time can be reduced to 7 cpu and also improves the utilization of memory. In this proposed algorithm, different types of denoising filters comparisons are discussed such as wiener filtering, inverse filtering, median filtering, trimmed average filtering. These filtering techniques have their unique advantages and disadvantages for appropriate noise. depends upon the distribution of noise ,characteristics of noise this proposed algorithm is finding the suitable denoising technique.

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