

# Comparative Study of Different Noise Models and Effective Filtering Techniques

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**Abstract:** Real world signals usually contain departures from the ideal signal that would be produced by our model of the signal production process. Such departures are referred to as noise. Noise arises as a result of unmodelled or unmodellable processes going on in the production and capture of the real signal. It may be caused by a wide range of sources, e.g. variations in the detector sensitivity, environmental variations, the discrete nature of radiation, transmission or quantization errors, etc. Digital Image processing system contains operators to artificially add noise to an image. Deliberately corrupting an image with noise allows us to test the resistance of an image processing operator to noise and assess the performance of various noise filters. Getting an efficient method of removing noise from the images, before processing them for further analysis is a great challenge for the researchers. The kind of the noise removal techniques to remove the noise depends on the type of noise present in the image. Best results are obtained if testing image model follows the assumptions and fail otherwise. In this paper, light is thrown on some important type of noise and a comparative analysis of noise removal techniques is done. This paper presents the results of applying different noise types to an image model and investigates the results of applying various noise reduction techniques.

**Keywords:** salt & pepper noise, Gaussian noise, speckle noise, Poisson noise, Median filter, Mean filter, Wiener filter. PSNR, MSE.

## 1. Introduction

Noise is a random variation of image Intensity and visible as grains in the image. It may arise in the image as effects of basic physics-like photon nature of light or thermal energy of heat inside the image sensors. It may produce at the time of capturing or image transmission. Noise means, the pixels in the image show different intensity values instead of true pixel values. Noise removal algorithm is the process of removing or reducing the noise from the image. The noise removal algorithms reduce or remove the visibility of noise by smoothing the entire image leaving areas near contrast boundaries. But these methods can obscure fine, low contrast details. The common types of noise that arises in the image are a) Impulse noise, b) Additive noise [1], c) Multiplicative noise. Different noises have their own characteristics which make them distinguishable from others. These noisy images and the Filtered images can be compared by applying the Histogram equalization techniques, which gives the detailed observations [14]. Comparing the Fourier transformation to the wavelet transformation gives better results [13]. But for prior study Fourier transform is good.

### 1.1 Various Sources 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. 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

### 1.2 The Additive Image Noise has some applications like:

- Signal estimation in presence of noise
- Detecting known features in a noisy background
- Coherent (periodic) noise removal

## 2. Why noise added?

Naturally Images contain some amount of noise. But its difficult to denoise it. So blind deconvolution is used. So a simulated noise is added to the image just to understand the process of denoising. Because after the addition of above mentioned noises if any other transformation or processing is done to the image then the corresponding noises will also be changed. There you will face difficulties to denoise if you don't know the type of noise. So a known noise is added to the image before processing.

For large numbers the Poisson distribution approaches a normal distribution, typically making shot noise in actual observations indistinguishable from true Gaussian noise except when the elementary events (photons, electrons, etc.) are so few that they are individually observed. Since the standard deviation of shot noise is equal to the square root of the average number of events  $N$ , the signal-to-noise ratio (SNR) is given by:

$$SNR = \frac{N}{\sqrt{N}} = \sqrt{N} \quad [ \text{Eq-1} ]$$

Thus when  $N$  is very large, the signal-to-noise ratio is very large as well, and any *relative* fluctuations in  $N$  due to other sources are more likely to dominate over shot noise.

## 2.1 Classification of Noise

**1. Independent noise:** Noise which is dependent on the image data. Image independent noise :can often be described by an additive noise model, where the recorded image  $f(i,j)$  is the sum of the *true* image  $s(i,j)$  and the noise  $n(i,j)$ : where  $n(i,j)$  is described by its variance.

$$f(i,j) = s(i,j) + n(i,j) \quad [\text{Eq-2}]$$

**2. Data-dependent noise:** This noise arising when monochromatic radiation is scattered from a surface whose roughness is of the order of a wavelength, causing wave interference which results in image *speckle*, it is possible to model noise with a multiplicative, or non-linear, model. These models are mathematically more complicated; hence, if possible, the noise is assumed to be data independent.

## 1.2 Noise Models

Noise may be modeled by either the Histogram or probability density function. Which is superimposed on original image. In the following, the most common types of noise will be presented.

**2.2.1 Gaussian Noise (Amplifier Noise)**

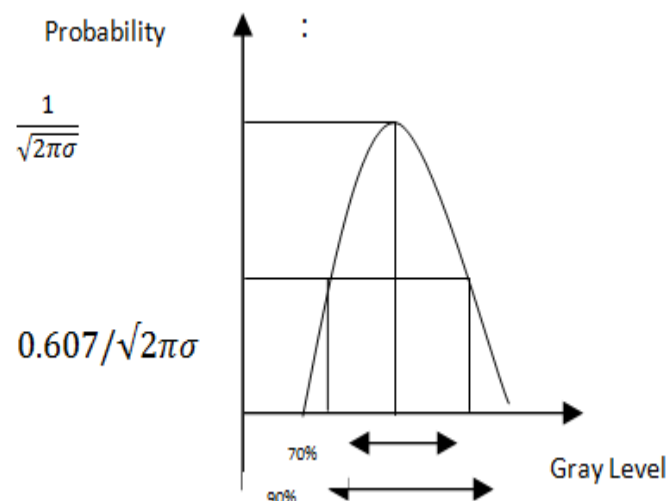
**2.2.2 Poisson Noise (Shot Noise)**

**2.2.3 Salt & pepper Noise (Impulse Noise)**

**2.2.4 Spackle Noise**

### 2.2.1 Gaussian Noise (Amplifier Noise)

Gaussian noise represents Statistical Noise having Probability Density Function(PDF) equal to that of the Normal distribution, which is also known as the Gaussian Distribution. It is a major part of the read noise of an image sensor that is of the constant level of noise in the dark areas. The probability density function  $P$  of a Gaussian random variable is given by



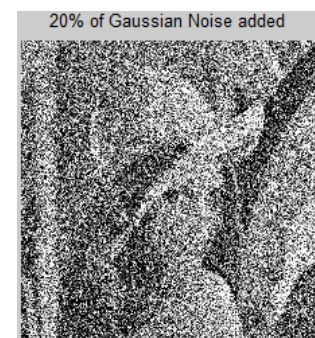
**Figure 1:** Probability density Function for Gaussian Noise model

$$P_g(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad [\text{Eq-3}]$$

where  $Z$  represents the grey level,  $\mu$  the mean value and  $\sigma$  the Standard Deviation.

Principal sources of Gaussian noise in digital images arise during acquisition e.g. sensor noise caused by poor illumination and/or high temperature, and/or transmission e.g. electronic circuit noise.<sup>[3]</sup> In digital image processing Gaussian noise can be reduced using a spatial filter.

## Experimental Results

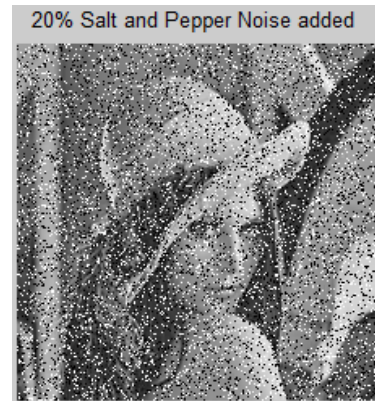


### 2.2.2 Poisson Noise (Shot noise)

The dominant noise in the lighter parts of an image from an image sensor is typically that caused by statistical quantum fluctuations, that is, variation in the number of photons sensed at a given exposure level. This noise is known as photon shot noise. Shot noise has a root-mean-square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows a Poisson distribution, which is usually not very different from Gaussian.

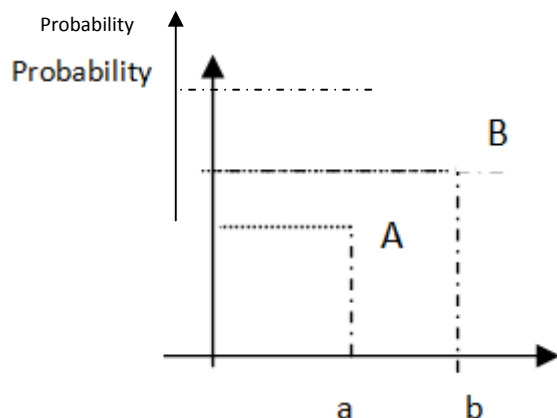
### Experimental results:





### 2.2.3 Salt and pepper Noise(Impulse Noise)

Another common form of noise is *data drop-out* noise (commonly referred to as *intensity spikes*, *speckle* or *salt and pepper noise*). Here, the noise is caused by errors in the data transmission. The corrupted pixels are either set to the maximum value (which looks like snow in the image) or have single bits flipped over. In some cases, single pixels are set alternatively to zero or to the maximum value, giving the image a 'salt and pepper' like appearance. Unaffected pixels always remain unchanged. The noise is usually quantified by the percentage of pixels which are corrupted. The typical intensity value for pepper noise is close to 0 and salt noise close to 255.



**Figure 2:** Probability density function for salt and pepper noise]

$$P(z) = \begin{cases} A & \text{for } g = a(\text{pepper}) \\ B & \text{for } g = b(\text{salt}) \end{cases} \quad [\text{Eq-4}]$$



### 2.2.4 Speckle Noise

Speckle noise can be modeled by random values multiplied by pixel values of an image.

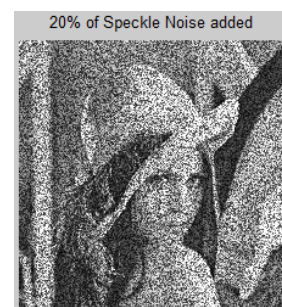
$J = \text{imnoise}(I, \text{'speckle'}, v)$  adds multiplicative noise to the image  $I$ , using the equation

$$J = I + n * I, \quad [\text{Eq-5}]$$

where  $n$  is uniformly distributed random noise with mean 0 and variance  $v$ . The default for  $v$  is 0.04.

The mean and variance parameters for 'Gaussian', 'localvar', and 'speckle' noise types are always specified as if the image were of class double in the range [0, 1]. If the input image is of class uint8 or uint16, the `imnoise` function converts the image to double, adds noise according to the specified type and parameters, and then converts the noisy image back to the same class as the input.

## Experimental Results



## 2.3 Denoising Techniques

There are basic two approaches of the image denoising: spatial domain filtering and transform domain filtering.

### 2.3.1 Spatial Domain Filtering

Spatial filters are direct and high speed processing tools of images. This is the traditional way to remove the noise from the digital images to employ the spatial filters. Spatial

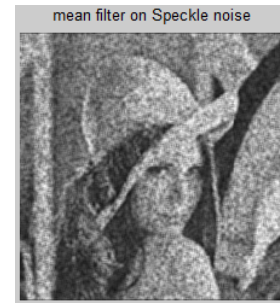
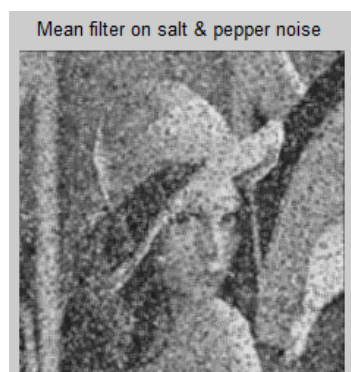
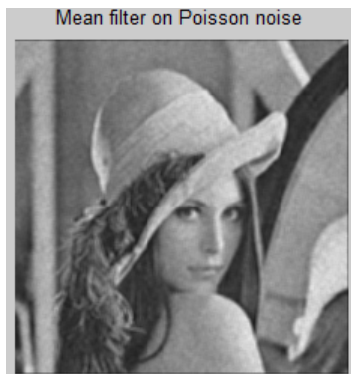
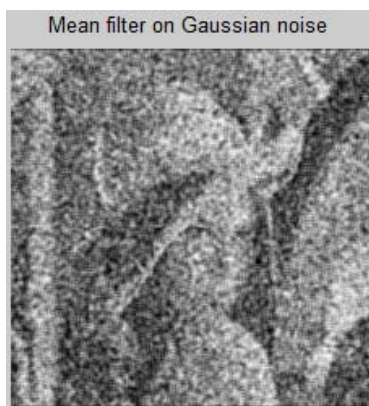


domain filtering is further classified into linear filters and non-linear filters.

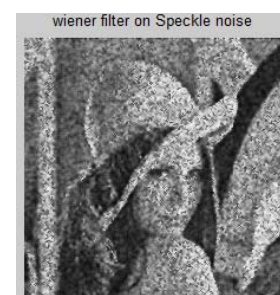
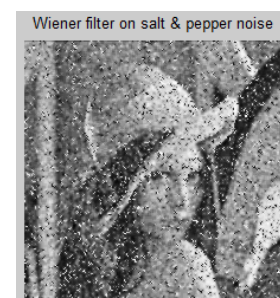
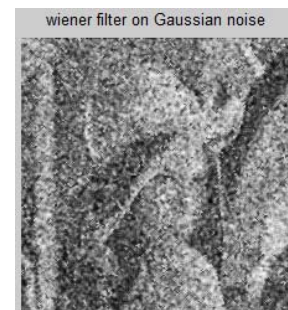
### 1) Linear filters

**a) Mean filter:** Mean filtering is a simple, intuitive and easy to implement method of smoothing images, *i.e.* reducing the amount of intensity variation between one pixel and the next. It is often used to reduce noise in images. The idea of mean filtering is simply to replace each pixel value in an image with the mean ('average') value of its neighbors, including itself. This has the effect of eliminating pixel values which are unrepresentative of their surroundings. The two main problems with mean filtering, which are:

- A single pixel with a very unrepresentative value can significantly affect the mean value of all the pixels in its neighborhood.
- When the filter neighborhood straddles an edge, the filter will interpolate new values for pixels on the edge and so will blur that edge. This may be a problem if sharp edges are required in the output.



**b) Wiener filter:** The wiener filtering method requires the information about the spectra of the noise and the original signal and it works well only if the underlying signal is smooth. Wiener method implements spatial smoothing and its model complexity control correspond to choosing the window size[7]. Wiener filtering is able to achieve significant noise removal when the variance of noise is low, they cause blurring and smoothening of the sharp edges of the image[8].



## 2) Non-linear filter

**a) Median filter:** Median filtering is a common step in image processing. Median filter is a well-used nonlinear filter that replaces the original gray level of a pixel by the median of the gray values of pixels in a specific neighborhood. The median filter is also called the order specific filter because it is based on statistics derived from ordering the elements of a set rather than taking the means. This filter is popular for reducing noise without blurring edges of the image[9]. It is particularly useful to reduce salt and pepper noise and speckle noise as well. Its edge preserving nature makes it useful in cases where edge blurring is undesirable.

### Experimental Results:



**Mean Square Error (MSE):** The MSE is the cumulative square error between the encoded and the original image defined by.

$$PSNR = 20 \log_{10} \left( \frac{MAX_f}{\sqrt{MSE}} \right) \quad [Eq-6]$$

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \|f(i,j) - g(i,j)\|^2 \quad [Eq-7]$$

Where,  $f$  is the original image and  $g$  is the uncompressed image. The dimension of the images is  $m \times n$ . Thus MSE should be as low as possible for effective compression.

**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 by:

Experimental Readings and Analysis of each Noise Model : Adding all kind of noise models on 10 different gray scale images gave various error result for each image. To analyze these errors the average of MSE and PSNR is calculated for individual noisy image as shown in table.

### Poisson noise:

**Table 1:** MSE and PSNR average results for Poisson Noise images

Filtering techniques	PSNR	MSE
Median Filter	5.7242	1.754
Mean Filter	5.7241	1.754
Wiener Filter	5.7244	1.754

### Gaussian noise:

**Table 2:** MSE and PSNR average results for Gaussian Noise images

Filtering techniques	PSNR	MSE
Median Filter	62.8884	0.0337
Mean Filter	65.8264	0.0171
Wiener Filter	64.8952	0.0212

### Salt and Pepper noise:

**Table 3:** MSE and PSNR average results for Salt and pepper Noise images

Filtering techniques	PSNR	MSE
Median Filter	74.2921	0.0024
Mean Filter	68.2633	0.0098
Wiener Filter	62.9285	0.0334

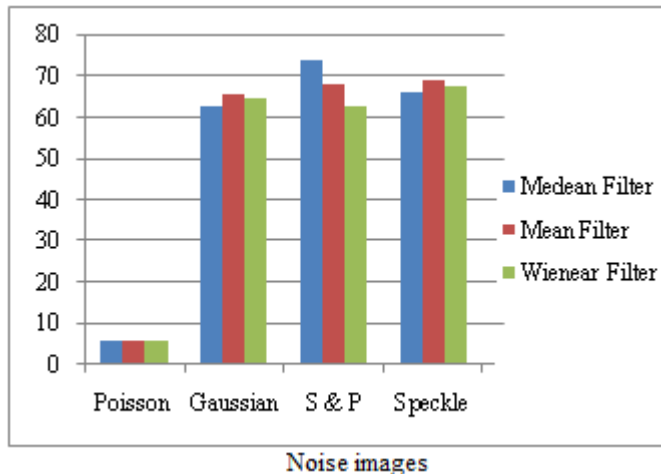
### Speckle noise:

**Table 4:** MSE and PSNR average results for Speckle

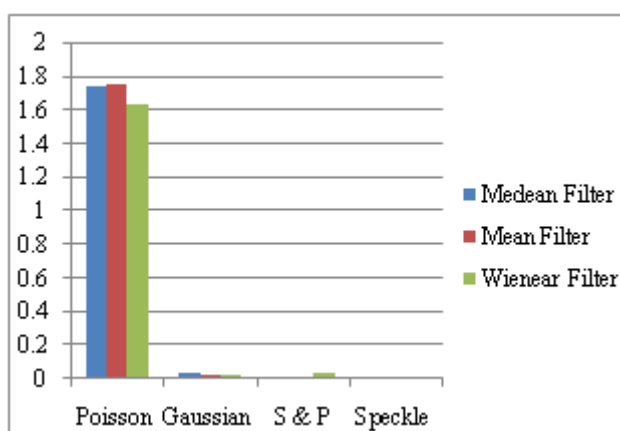
Filtering techniques	PSNR	MSE
Median Filter	66.1911	0.0158
Mean Filter	69.2023	0.0079
Wiener Filter	67.6572	0.0112

## 3. Performance Parameters:

For comparing original image and uncompressed image, we calculate following parameters:



**Graph 1:** Graphical representation of PSNR values for Filtered images



**Graph 2:** Graphical representation of MSE values for Filtered images

#### 4. Conclusion

Enhancement of a noisy image is necessary task in digital image processing. To rectify the noise content in the natural image by adding known noise to the image before processing. So a simulated noise is added to the image just to understand the process of denoising. In this paper, we have discussed different types of noise that creep in images during image acquisition or transmission. Light is also thrown on the causes of these noises and their major sources. In the second section we present the various filtering techniques that can be applied to de-noise the images. After observing the results of PSNR and MSE values it concludes that median filter works better in denoising the image in all the noise models.

#### 5. Future Scope

By observing these experimental values and result of each filtered image one can easily justify the which filtering technique is applied n what kind of image. These observations will help to try on different area of image like medical image, satellite image, bio metric image, Video images etc. to get the fast and efficient results.

#### References

- [1] R. Gonzales and R. Woods *Digital Image Processing*, Addison Wesley, 1992, pp 187 - 213.
- [2] A. Jain *Fundamentals of Digital Image Processing*, Prentice Hall, 1989, pp 244 - 253, 273 - 275.
- [3] Dr. Philippe Cattin (2012-04-24). "Image Restoration: Introduction to Signal and Image Processing". MIAC, University of Basel. Retrieved 11 October 2013.
- [4] John Wiseman, An Introduction to MPEG Video Compression, [http://www.johnwiseman.com/technical/MPEG\\_tutorial.htm](http://www.johnwiseman.com/technical/MPEG_tutorial.htm), retrieved 6 Nov 2010.
- [5] Tudor Barbu (2013). "Variational Image Denoising Approach with Diffusion Porous Media Flow". Abstract and Applied Analysis 2013: 8. doi:10.1155/2013/856876.
- [6] Barry Truax, ed. (1999). "Handbook for Acoustic Ecology" (Second ed.). Cambridge Street Publishing. Retrieved 2012-08-05.
- [7] Dr. Philippe Cattin (2012-04-24). "Image Restoration: Introduction to Signal and Image Processing". MIAC, University of Basel. Retrieved 11 October 2013.
- [8] Robert Fisher, Simon Perkins, Ashley Walker, Erik Wolfart. "Image Synthesis — Noise Generation". Retrieved 11 October 2013.
- [9] K. S. Srinivasan and D. Ebenezer, "A New Fast and Efficient Decision-Based Algorithm for Removal of High-Density Impulse Noises," IEEE Signal Processing Letters, Vol. 14, No. 3, March 2007.
- [10] H. Hwang and R. A. Haddad "Adaptive Median Filters: New Algorithms and Results" IEEE Transactions on image processing vol 4. P.no 499-502, Apr 1995.
- [11] Nachtegaal, M, Schulte, S, Vander Weken. Kerre, E.E.2005.Fuzzy Filters for Noise Reduction: The Case of Gaussian Noise. IEEE Xplore, 201-206 D, De Witte, V, 206.
- [12] Suresh Kumar, Papendra Kumar, Manoj Gupta, Ashok Kumar Nagawat, "Performance Comparison of Median and Wiener Filter in Image De-noising" ,International Journal of Computer Applications (0975 – 8887) Volume 12– No.4, November 2010.
- [13] Aziz Ur Rahaman Makandar, "Medical Image Compression Using Orthogonal and Biorthogonal Wavelet Transform" Indian Stream Research Journal, Oct 2012, pp Vol 2, Issue 9,1-9,ISSN 2230-7850.
- [14] Aziz Makandar, Anita Patrot,Bhagirathi Halalli, "Color Image analyses and contrast stretching using Histogram equalization", IJAIST Vol 27 No.27 July 2014,ISSN 2319: 2682:

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