# Image Denoising for different noise models by various filters: A Brief Survey

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## Abstract

***Image denoising has been a serious problem in the field of image processing. Many algorithms have been implemented for denoising algorithms and each algorithms has its advantages and limitations. Having a good knowledge about the noise present in the image will be crucial in selecting a suitable denoising algorithm. The significance of the image denoising could be a weighty task for medical imaging, satellite image processing, and space exploring etc. A wide variety of noise types are present and good number of denoise filters have been developed to reduce noise from degraded images to enhance image quality by preserving edges. This paper is a review of some of the extensive work in the existing denoising algorithms and their performance as a comparative study.***

**Keywords:-** Image denoising, median filter, mean filter, weiner filter

## 1. INTRODUCTION

Digital images are playing a prominent role in research and technology such as environmental information systems. Degrading noise, which are incurred during the image capturing process must be removed or reduced by denoising methods to improve the quality of the image. Existing varieties of noise types, noise models and denoising methods are discussed in this paper.

### 1.1 Image Restoration

The objective of image restoration procedures is to suppress degradation of the image with the help of the knowledge about its nature. The image degradation could be attributed to the defects present in the optical lenses, relative motion between the object and the camera, wrong focus, turbulence in the atmosphere, scanning quality etc.
The goal of image restoration is to reconstruct the original image from its degraded form. The image restoration techniques can be broadly classified into two groups as: (i) deterministic and (ii) stochastic. Deterministic method suits in restoring images with a little noise and a known degradation function. The original image can be obtained by applying a transformation inverse to the degradation of the degraded image. Stochastic technique tries to find the best restoration according to a particular stochastic criterion.

### 1.2 Noise Process:

Noise in the image may be introduced either during its formation or during its recording. For instance the noise that is introduced in a photographic film is due to the function of the formation which is the recording mechanism. The two separate processes that are likely to contribute to the noise in the images are (i) random fluctuations in the number of photons and the photoelectrons on the photoactive surface of the detector and (ii) the random thermal noise which is generated in the circuit that senses the image, acquires it and processes the signal from the detector's photoactive surface. Noise may also be introduced during the transmission of radiant energy. It is evident that the noise introduced in the acquiring process of the image is partly signal dependent and partly signal independent additive noises.

## 2. VARIOUS NOISE MODELS IN IMAGES

The images are degraded by noise which is some random error. Noise could be picked along with the image during capturing, transmitting or during the processing. It could be dependent or independent of the image content. Variety of noise models are used to create different types of noise for the images. The probabilistic characteristics of the noise can be used to describe it. The often used idealized noise, which is also called white noise, has the intensity that does not decrease with increasing frequency. A special case of white noise is Gaussian noise. A random variable with Gaussian distribution has its probability density given by the Gaussian curve. Noise which is normally dependent of the images signal occurs when an image is transmitted through some channel. This signal independent degradation is called additive noise and this can be described by the model

$$f(x, y) = g(x, y) + \nu(x, y) \qquad (1)$$

where the noise ν and the input image g are independent variables. In many cases the magnitude of the noise depends on the very signal magnitude. When the noise magnitude is much higher in comparison with the signal, this model describes multiplicative noise. Quantization noise (Uniform noise) occurs when insufficient quantization levels are used, for instance, 50 levels for a monochromatic image. Presence of impulse noise implies that an image is corrupted with individual noisy pixels whose brightness differs significantly from that of its neighborhood. The term salt-and-pepper noise is used to describe saturated impulse noise, i.e., an image corrupted with white and/or black pixels . Salt-and-pepper noise can corrupt the binary images.

Some of the types of models for the noise term ν(x,y) :

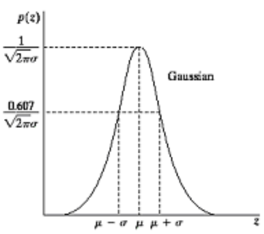


**Figure 1** Gaussian Noise

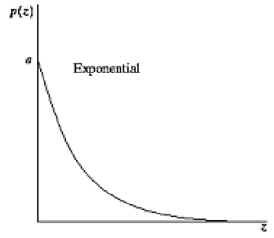


**Figure 2** Exponential Noise

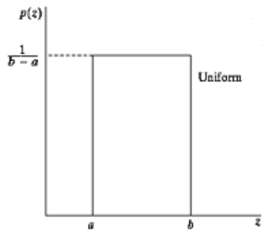


**Figure 3** Uniform Noise

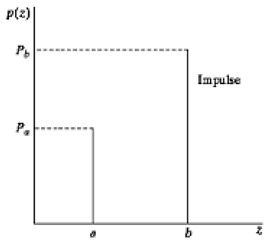


**Figure 4** Impulse (Salt and pepper) Noise

## 3. CLASSIFICATION OF DENOISING TECHNIQUES

The basic idea of the determination of a non degraded image from the degraded or noisy image, and is referred to as image "denoising". Denoising method selection is based upon the type of image and noise model present in it. There are two fundamental approaches to image denoising: (i) spatial domain filtering and (ii) transform domain filtering . The detail classification is shown in the following figure:

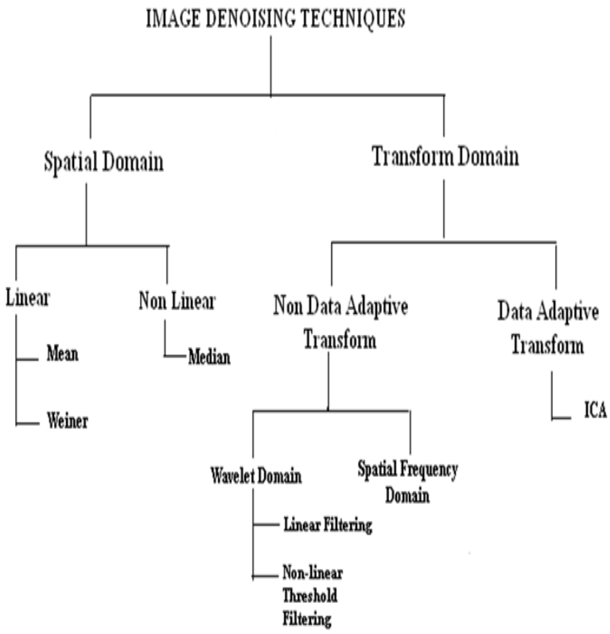


**Figure 5** Classification of Image Denoising Techniques

### 3.1 Spatial Domain

A direct procedure to remove noise from an image is to utilize spatial filters, which can be classified into non-linear and linear filters. Filtering in image processing is a function that is used to perform many tasks like noise reduction, interpolation, and re-sampling. The perfect choice of the filter is identified by the nature of the task performed by filter and type of the data. In image processing, filters are used to remove noise from an image while preserving the original image.

#### 3.1.1 Non-Linear Filters

Non-linear filters are used to remove the noise without any effort to explicitly identify it. These filters often remove noise to a reasonable extent but at the cost of blurring images and consequently makes the edges in image invisible. Recently a variety of nonlinear median type filters such as weighted median [1], rank conditioned rank selection [2], and relaxed median [3] have been developed to overcome this disadvantage.

**(a) Median Filter**

The Median filter is a non-linear smoothing technique that reduces the blurring of edges; here the idea is to replace the current point in the image by the median of the brightness in its neighborhood. The median of the brightness in the neighborhood is not affected by individual noise spikes. The median filter eliminates impulse noise efficiently. Since median filtering does not blur edges much, it can be applied iteratively. One of the major problems with the median filter is that it is relatively expensive and is hard to compute. It is essential to sort all the values in the neighborhood into numerical in order to find out the median value which is relatively slow.

#### 3.1.2 Linear Filters

Mean filter is the optimal linear filter for Gaussian noise in the sense of mean square error. Linear filters too weak to blur the original sharp edges, destroy lines and other image details, and perform in the presence of signal-dependent noise. The wiener filtering [11] method requires the information about the spectra of the noise and the original signal and it works well only when the original signal is smooth.

**(a) Mean Filter**

Mean filtering is a simple method of *denoising* images, *i.e.* reducing the amount of intensity variation between one pixel and the next. The basic idea of mean filtering is to replace each pixel value in an image with the mean (`average') value of its neighbors together with itself. This has the effect of eliminating pixel values which are unreliable of their surroundings. Often 3×3 square kernal is used. Computing the straightforward convolution of an image with this kernel carries out the mean filtering process.

$$MeanFilter(X1,....Xn) = -\sum_{i=1}^{N} Xi \quad (2)$$

where (x1 ….. xN) is the image pixel range. There are two main problems in mean filtering. They are:

- A single pixel with a very unrepresentative value can significantly affect the mean value of all the pixels in its neighborhood.

- The filter will insert new values for pixels on the edge and subsequently will end up in blurring the edge. If sharp edges are required in the result then this may not be desirable.

**(b) Weiner Filter**

Weiner filtration [4] gives an estimate of the original uncorrupted image with minimal mean square error; the optimal estimate is in general a non-linear function of the corrupted image.
The function can be written by,

$$f(u,v) = \left[ \frac{H(u,v)^*}{H(u,v)^2 \left[ Sn(u,v)/Sf(u,v) \right]} \right] G(u,v) \quad (3)$$

where H(u, v) is the degradation function , H(u, v)* is its conjugate complex and G(u, v) is the degraded image. Functions Sf(u, v) and Sn(u, v) are power spectra of the original image and the noise. Wiener Filter assumes noise and power spectra of object a priori.

**3.2 Transform Domain**

The transform domain filtering approach is classified based on the basis functions. These functions can be further classified as (i) Non-data adaptive functions and (ii) Data adaptive functions.
3.2.1 Non-Data Adaptive Transforms

**(a) Spatial-Frequency Filtering**

Spatial frequency filtering method is a form of transform domain filtering. It uses Fast Fourier Transform (FFT) with low pass filters (LPF) . In Spatial-Frequency method [5], denoising is done by designing a cut-off frequency. But these are time consuming and may produce non-natural frequencies in processed image.

**(b) Wavelet Domain**

Wavelet Domain filtering is divided into two distinct techniques called (i) linear and (ii) non-linear.

**(1) Linear Filters**

Wiener filter is the generally used linear filtering method which yields most valuable outcomes in the wavelet domain filtering. It is used where data degradation can be modeled as a Gaussian process and accuracy criterion is mean square error [6], [7]. But this filtering result is visually more inadequate than original degraded image.

**(2) Non-Linear Threshold Filtering**

Non-Linear threshold filtering uses the wavelet transform that maps noise in signal domain to that of noise in transform domain. While signal energy becomes more concentrated into fewer coefficients in transformation domain noise energy does not. Two types of thresholding functions are used . They are, (i) Hard threshold [8] and (ii) Soft threshold. If the input is larger than the threshold, then it is kept as a Hard-Thresholding function, it is set to zero otherwise. The input arguments are reduced toward zero by the threshold, called Soft-thresholding function [9]. The result may still be noisy. Signal with large number of zero coefficients is produced by large threshold. This leads to a smooth signal. Selection of an optimal threshold is done with great attention.

**3.2.2 Data-Adaptive Transforms**

Independent Component Analysis (ICA) transformation methods are more important which includes key component, factor analysis and projection detection. ICA is the most widely used method for blind source partition problem. The major advantage of using ICA is it's assumption of signal to be Non-Gaussian which helps denoising of images with Non-Gaussian as well as Gaussian distribution. Demerits of ICA based techniques is the computational cost because it uses a sliding window and involves sample of at least two image frames of the same scene as in [10].

## 4. DISCUSSION

The comparative study of different denoising methods performance for digital images is measured by some quantitative performance measures like peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR). It shows that wavelet filters perform better than spatial domain filters. Spatial filters do have some constraints like resolution degradation. They operates on images over a fixed windows that leads the image to blur. Mean filter and median filters are good in impulse noise removal. The implementation of these filters is easy, very fast and cost effective. The median filter produces the denoised image in which the sharpness of the image is retained. It can be concluded that the median filter is most suitable for the salt and pepper noise. Wavelet transform is best suited in terms of performance because of its attributes such as multiresolution and multiscale nature. It produces the denoised image with shaper edges while preserving its fine texture information. Wavelets play a vital role in the noise removal for the Gaussian type of noises. The major role of this paper is subject to smooth the degraded image with any kind of denoising methods for desired edge preservation.

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