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Image Denoising Using Different Filters (A Comparison of Filters)

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Abstract

Image processing is basically the use of computer algorithms to perform image processing on digital images. Image denoising adds the manipulation of the image to produce a high quality image. The main criteria of Image denoising are to restore the detail of original image as much as possible. Image processing provides much range of algorithms to be applied to the input data and can remove problems such as the increase of noise and signal distortion during processing of images. Different types of noise models including additive and multiplication types are used. In this work four types of noise (Amplifier noise, Salt & Pepper noise, Speckle noise and Poisson noise) is used and image de-noising performed for different noise by Inverse filter, Wiener filter and Lucy-Richardson method. Selection of the denoising algorithm is based on the using noise and filter in image processing. Hence, it is very important to know about the noise present in the image and select the appropriate denoising algorithm. The filtering approach has defined the best results when the image is corrupted with salt and pepper noise. In this paper, we introduce some important type of noise and a comparative analysis of noise removal techniques is applied. The experimental results are discussed and analyzed to determine the overall advantages and disadvantages of each category.

Keywords: *Image noise modal, filters, Gaussian noise, salt and pepper noise, speckle noise, Poisson noise.*

1. Introduction

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. Image de-noising is an vital image processing task i.e. as a process itself as well as a component in other processes. There are many ways to de-noise an image or a set of data and methods exists. The important property of a good image denoising model is that it should completely remove noise as far as possible as well as preserve edges. 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 c) Multiplicative noise. 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. Image

Enhancement is simple and most appealing area among of the digital image processing techniques. The main purpose of image enhancement is to bring out detail that is hidden in an image or to increase contrast in a low contrast image.

2. Various sources of noise in image

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.

3. Image noise

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is generally regarded as an undesirable by-product of image capture. Although these unwanted fluctuations became known as "noise" by analogy with unwanted sound they are inaudible and such as dithering. The types of Noise are following:-

• Amplifier noise (Gaussian noise)
• Salt-and-pepper noise
• Shot noise (Poisson noise)
• Speckle noise

3.1 Gaussian noise

The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity. In color cameras where more amplification is used in the blue color channel than in the green or red channel, there can be more noise in the blue channel. Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image. Fig. 2 Show the effect of this noise on the original image.

Fig 1. Original image without noise

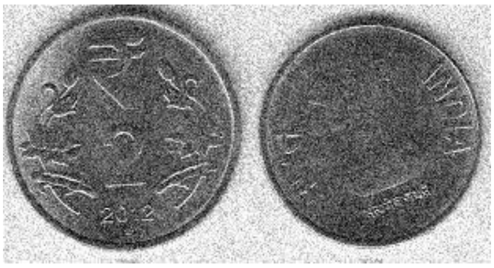

Fig 2, Gaussian noise

3.2 Salt-and-pepper noise

An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by dead pixels, analog-to-digital Converter errors, bit errors in transmission, etc. This can be eliminated in large part by using dark frame subtraction and by interpolating around dark/bright pixels.

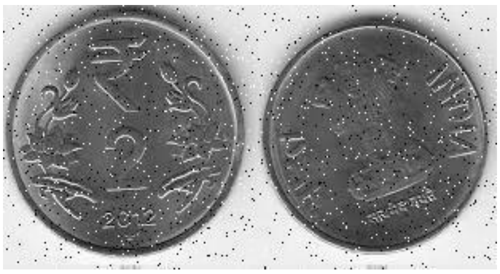

Fig.3, salt & pepper noise

3.3 Poisson noise

Poisson noise or shot noise is a type of electronic noise that occurs when the finite number of particles that carry energy, such as electrons in an electronic circuit or photons in an optical device, is small enough to give rise to detectable statistical fluctuations in a measurement.

Fig.4, Image with Poisson noise

3.4 Speckle noise

Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar (SAR) images. Speckle noise in conventional radar results from random fluctuations in the return signal from an object that is no bigger than a single image-processing element. It increases the mean grey level of a local area. Speckle noise in SAR is generally more serious, causing difficulties for image interpretation. It is caused by coherent processing of backscattered signals from multiple distributed targets. In SAR oceanography, for example, speckle noise is caused by signals from elementary scatters, the gravity-capillary ripples, and manifests as a pedestal image, beneath the image of the sea waves.

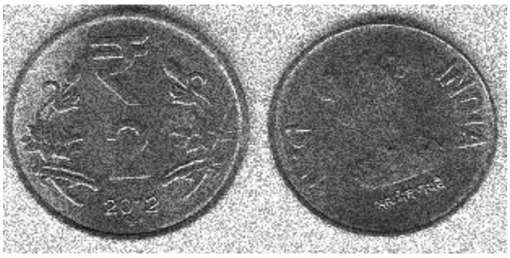

Fig. 5, Image with speckle noise

4. Filters used for Image Denoising

4.1 Wiener Filter

The purpose of the Wiener filter is to filter out the noise that has corrupted a signal. This filter is based on a statistical approach. Mostly all the filters are designed for a desired frequency response. Wiener filter deal with the filtering of an image from a different view. The goal of wiener filter is reduced the mean square error as much as possible. This filter is capable of reducing the noise and degrading function. One method that we assume we have knowledge of the spectral property of the noise and original signal. We used the Linear Time Invariant filter which gives output similar as to the original signal as much possible.

Characteristics of the wiener filter are-

a. Assumption: signal and the additive noise are stationary linear-random processes with their known spectral characteristics.
b. Requirement: the wiener filter must be physically realizable, or it can be either causal
c. Performance Criteria: There is minimum mean-square [MSE] error.

The Fourier domain of the Wiener filter is-

$$\boldsymbol{G(u,v)} = \frac{\boldsymbol{H^*(u,v)}}{\boldsymbol{|H(u,v)|^2 P_s(u,v) + P_s(u,v)}}$$

Where,

H(u, v)* = Complex conjugate of degradation function

Pn (u, v) = Power Spectral Density of Noise

Ps (u, v) = Power Spectral Density of non-degraded image

H (u, v) = Degradation function

4.2 Inverse Filter

The inverse filter is a straight forward image – restoration method..If we know the exact psf model in the image degradation system and ignore the noise effect, the degraded image can be restored using the inverse filter.

If we know or can create a good model of the blurring function that corrupted an image, the quickest and easiest way to restore that is by inverse filtering. Unfortunately, since the inverse filter is a form of high pass filer, inverse filtering responds very badly to any noise that is present in the image because noise tends to be high frequency. In this section, we explore a method of inverse filtering called a thresholding method.

We can model a blurred image by-

f (x, y)** h(x, y) =d(x, y)

Where f is the original image, h is some kind of a low pass filter and d is our blurred image. So to get back the original image, we would just have to convolve our blurred function with some kind of high pass filters are

r(x, y)** d (x, y) =f (x, y)

4.3 Lucy-Richardson method

The restoration methods which are discussed above are linear. They are also direct in the sense that, once the restoration filter is specified, the solution is obtained in one go. During the past two decades, non-liner iterative methods have been gaining there acceptance as restoration tool that often yield result better than those obtained with linear methods. The Lucy Richardson (LR) algorithm is an iterative nonlinear restoration method. The L-R algorithm arises from maximum likelihood formulation in which image is modeled with poison statistics.

While using this method, there arises an obvious question of where to stop. It is difficult to claim any specific value for the number of iterations; a good solution depends on the size and complexity of the PSF matrix. The algorithm usually reaches a stable solution very quickly (few steps) with a small PSF matrix. But if one stops after a very few iterations then the image maybe very smooth. On the other hand, increasing the number of iterations not only slows down the computational process, but also amplifies noise and introduces the ringing effect. Some additional methods for ringing reduction are given in [9]. Thus for the "good" quality of restored image, the optimal number of iterations are determined manually fore very image as per the PSF size.

5. Performance parameters

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

5.1 Mean Square Error (MSE)

The MSE is the cumulative square error between the encoded and the original image defined by: Where, f is the original image and g is the uncompressed image. The dimension of the images is m x n. Thus MSE should be as low as possible for effective compression.

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

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 by-

$$PSNR = 20log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$$

Where MAX_f is the maximum signal value that exists in our original "known to be good" image.

6. Discussion of Result

In Original Image, adding four types of Noise (Gaussian noise, Poisson noise, Speckle noise and Salt & Pepper noise).adding the noise with standard deviation(0.025) and De-noised image using Inverse filter, Wiener filter and Lucy- Richardson method comparisons among them.

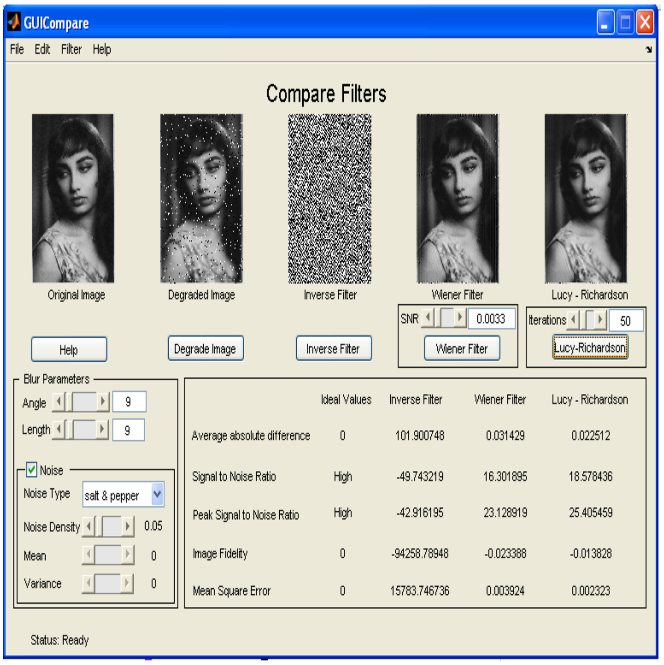

Fig.6 Image with Salt and pepper noise

Fig.6 shows the image with salt and pepper noise and these noises passes through different filters and compare the result.

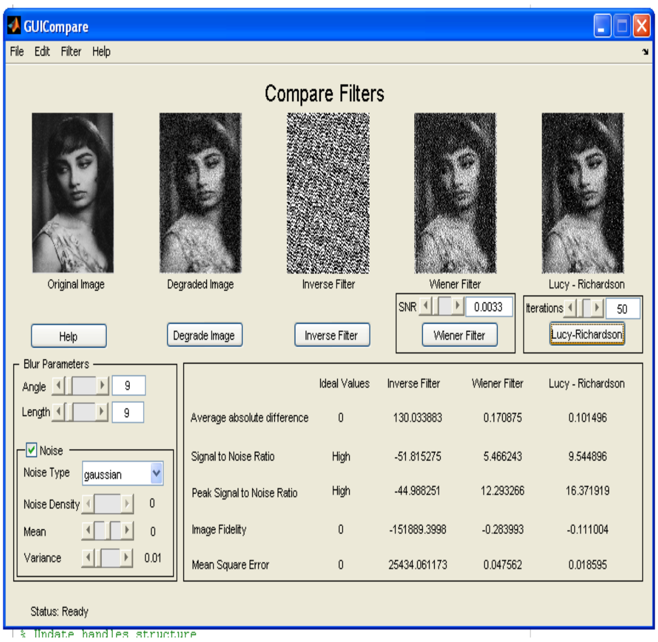

Fig.7 Image with Gaussian noise

Fig. 7 shows the image with Gaussian noise and these noises passes through different filters and compare the result.

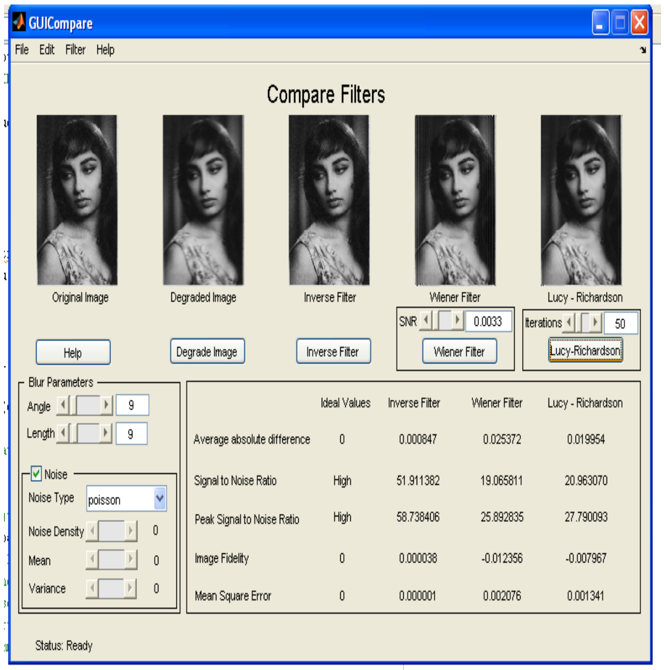

Fig.8 Image with Poisson noise

Fig.8 shows the image Poisson noise and these noises passes through different filters and compare the result.

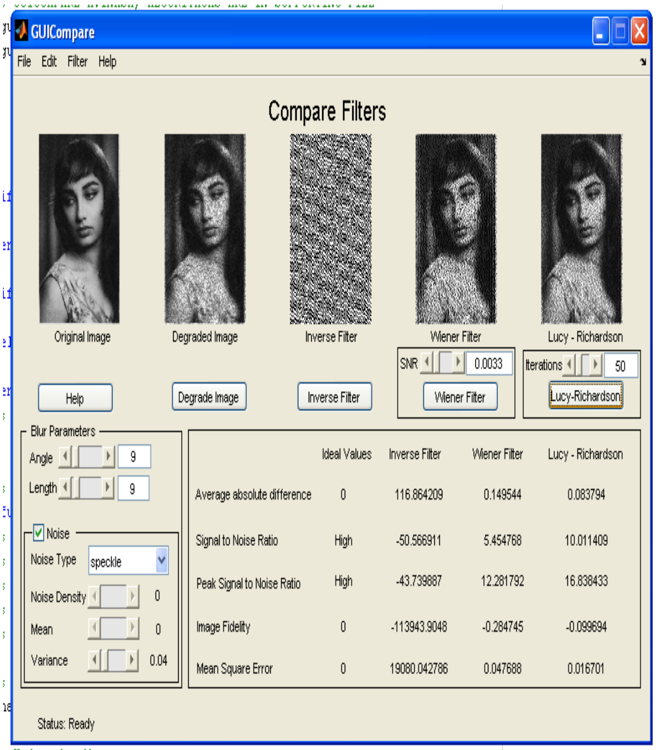

Fig. 9 Image with Speckle noise

Fig.9 shows the image Speckle noise and these noises passes through different filters and compare the result.

TABLE 1. PSNR in dB

Filters	**Salt & pepper noise**	**Gaussian noise**	**Poisson noise**	**Speckle noise**
Inverse filter	-42.91	-44.988	58.738406	-43.7398
Wiener filter	23.1289	12.2932	25.892835	12.281792
Lucy-Richardson method	25.405	16.3719	27.790093	16.838433

TABLE 2. MSE of Different Noises

Filters	**Salt & pepper noise**	**Gaussian noise**	**Poisson noise**	**Speckle noise**
Inverse filter	15783.7467	25434.061	0.000001	19080.042786
Wiener filter	0.003924	0.047562	0.002076	0.047688
Lucy-Richardson method	0.002323	0.018595	0.001341	0.016701

7. Conclusion

In this paper, we reviewed and compared representative denoising methods both qualitatively and quantitatively, and 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. Experimental results presented, insists us to conclude that Wiener filter, Lucy-Richardson method performed well. The performance of the Wiener Filter after denoising for all Speckle, Poisson and Gaussian noise is better than other filters.

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