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# A Study on Image Restoration Techniques

**Ms.S.Maheshwari**
Department of Computer Science & Bharathiar University

***Abstract*— Images play an important role in research and technology. But the main drawback in digital images is presence of noise and degradation during their acquisition or transmission. One of the important image processing techniques is image restoration. Image restoration aims at improving the quality of an image by removing defects and makes it better. It is widely used in various fields of applications, such as medical imaging, astronomical imaging, remote sensing, microscopy imaging, photography, and forensic science, etc. Image restoration is one of the active fields in research. This paper gives basic information on the image restoration and various deblurring and denoising techniques**.

***Keywords*— Image restoration, Noise, Degradation, Deblurring, Denoising**

## I. INTRODUCTION

Images play a vital role by displaying useful information. There are various techniques that are developed to support variety of image processing applications. Image restoration is concerned with the reconstruction and estimation of uncorrupted image from a blurred and noisy image. It is an objective process which tries to recover the original signal from its measured deteriorated version on the basis of some knowledge of the properties of deterioration. The corruption may be in many forms such as blur, noise and camera misfocus. The main objective is to improve the quality and appearance of the image by removing the defects and make a better image. Before the restoration process, estimation of the attributes of imperfect imaging system from the observed degraded image should be concerned.

Any image captured by optical, electro-optical or Electronic means is likely to be degraded by the sensing environment.

Image Restoration is concerned with filtering the observed image to minimize the effect of degradations. The effectiveness of Image Restoration filters depends on the accuracy of the knowledge of the degradation process as well as the filter design criterion. It deals with the reconstruction or estimation of the uncorrupted image from a blurred and noisy one and improving the appearance of the image.

## II. DEBLURRING

Blurring is the form of bandwidth reduction of images caused by imperfect image formation process. The task of deblurring, a form of image restoration, is to obtain the original, sharp version of a blurred image.

Blurring an image usually makes the image unfocused. In signal processing, blurring is generally obtained by convolving the image with a low pass filter. The amount of blurring is increased by increasing the pixel radius. The blurring is characterized by a Point-Spread Function (PSF) or impulse response. The PSF is the output of the imaging system for an input point source.

A blurred or degraded image can be approximately described by this equation

$$\mathbf{g = Hf + n},$$

where

**g**-The blurred image

**H** -The distortion operator also called the point spread function (PSF).

**f**-The original true image

**n**- Additive noise, introduced during image acquisition, that corrupts the image

### *A. Blurring Types*

There are different types of blur.

#### *1) Average Blur*

The Average blur is one of used to remove noise and specks in an image and also when noise is present over the entire image. This type of blurring can be distribution in horizontal and vertical direction and can be circular averaging by radius R which is evaluated by the formula:

$$R = \sqrt{g2 + f2}$$

Where

g - is the horizontal size blurring direction

f - vertical blurring size direction and

R - the radius size of the circular average blurring.

*2) Gaussian Blur*

The Gaussian Blur effect is a filter that blends a specific number of pixels incrementally, following a bell-shaped curve. Gaussian Blur filter is applied to an image when more control over the Blur effect is needed.

*3) Motion Blur*

The Many types of motion blur can be distinguished all of which are due to relative motion between the recording device and the scene. This can be in the form of a translation, a rotation, a sudden change of scale, or some combinations of these. The Motion Blur effect is a filter that makes the image appear to be moving by adding blur in a specific.

*4) Out of Focus Blur*

When a camera images a 3-D scene onto a 2-Dimaging plane, some parts of the scene are in focus while other parts are not. If the aperture of the camera is circular, the image of any point source is a small disk, known as the circle of confusion (COC).The degree of defocus (diameter of the COC) depends on the focal length and the aperture number of the lens, and the distance between camera and object.

B. *Deblurring Techniques*

*1) Wiener Filter De-blurring Technique*

Wiener filter's working principle is based on the least squares restoration problem. It is a method of restoring image in the presence of blur and noise. It removes the additive noise and inverts the blurring simultaneously. It not only performs the deconvolution by inverse filtering (high pass filtering) but also removes the noise with a compression operation (low pass filtering).It compares with an estimation of the desired noiseless image. The input to a wiener filter is a degraded image corrupted by additive noise.

**a)** **b)** **c)**

Fig 1: Wiener Filter a) Original Image b) Blurred Image c) Restored Image

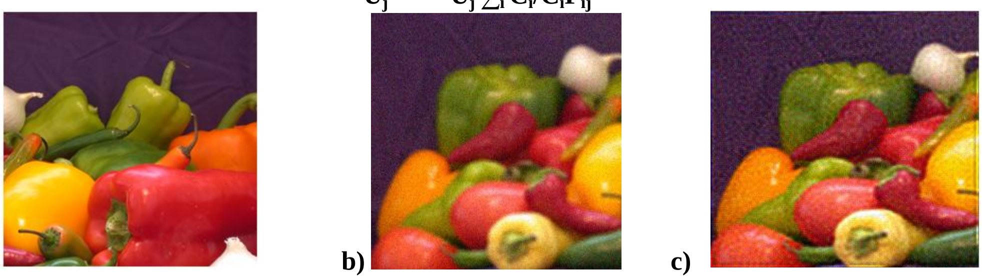
*2) Lucy- Richardson Algorithm Technique*

The Richardson–Lucy algorithm, also known as Richardson–Lucy deconvolution, is an iterative procedure for recovering a latent image that has been the blurred by a known PSF.

$$\mathbf{C_i} = \sum_j P_{ij} . U_j$$

Where $P_{ij}$ is the point spread function (the fraction of light coming from true location j that is observed at position i), $U_j$ is the pixel value at location j in the latent image, and $C_i$ is the observed value at pixel location i. The statistics are performed under the assumption that $U_j$ are Poisson distributed which is appropriate for photon noise in the data. The basic idea is to calculate the most likely $U_j$ given the observed $\mathbf{C_i}$ and known $P_{ij}$. This leads to an equation for $U_j$ which can be solved iteratively according to:

$$\mathbf{U_j^{(t+1)} = U_j^{t} \sum_i C_i / C_i P_{ij}}$$



**a)** **b)** **c)**

Fig 2: Lucy- Richardson Algorithm a) Original Image b) Blurred and Noisy image c) Restored Image

## III. DENOISING

The original meaning of noise is unwanted signal. Noise in images are mainly due to capturing instruments, transmission medium, recording medium, image quantization for storage, sources of radiation and compression. It is an unwanted signal that interferes with the original signal and degrades the quality of digital image. The introduced noise may of different kinds upon which the amount of degradation varies. There are different types of noise models for different types of noises. Noise is present in image either in additive or multiplicative form.

*C. Image Noise*

The main source of noise in digital images arises during image acquisition (digitization) or during image transmission

*1) Additive Noise Model*

Noise signal that is additive in nature gets added to the original signal to produce a corrupted noisy signal and follows the following model:

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

*2) Multiplicative Noise Model*

In this model, noise signal gets multiplied to the original signal. The multiplicative noise model follows the following rule:

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

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

*3) Uniform noise*

The noise caused by quantizing the pixels of a sensed image to a number of discrete levels is known as quantization noise. It has an approximately uniform distribution. In the uniform noise the level of the gray values of the noise are uniformly distributed across a specified range. Uniform noise can be used to generate any different type of noise distribution. This noise is often used to degrade images for the evaluation of image restoration algorithms.

*4) Gaussian noise*

The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity. Gaussian noise is evenly distributed over the signal. This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value.

*5) Salt-and-pepper noise*

An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. It is generally caused due to errors in transmission. This is caused generally due to errors in data transmission. It has only two possible values, a and b. The probability of each is typically less than 0.1. The corrupted pixels are set alternatively to the minimum or to the maximum value, giving the image a “salt and pepper” like appearance. Unaffected pixels remain unchanged.

*6) Speckle noise*

Speckle noise is multiplicative noise. Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar images. 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. The source of this noise is attributed to random interference between the coherent returns.

*D. Denoising techniques*

Various denoising techniques are used which are basically dependent on the type of image and type of noise model. There are two approaches to image denoising.

*1) Spatial Domain Filtering*

The traditional way to remove noise from the digital image is to employ the spatial filters. Spatial domain filtering is further classified into linear filters and non-linear filters.

*i) Linear Filters*

Linear filters tend to blur sharp edges, destroy lines and other fine details of image. It includes Mean filter and Wiener filter.

*Mean Filter*

Mean filter is a simple sliding window spatial filter that replaces the center value in the window with the average of all the neighboring pixel values including it. It is also called a linear filter. The mean filter is useful when only a part of the image needs to be processed.

*Weiner Filter*

Weiner filtering method requires the information about the spectra of noise and original signal and it works well only if the underlying signal is smooth. Weiner method implements the spatial smoothing and its model complexity control corresponds to the choosing the window size. Wiener Filter assumes noise and power spectra of object a priori.

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

where

$H(u, v)$ = Degradation function

$H^{*}(u, v)$ = Complex conjugate of degradation function

$P_n(u, v)$ = Power Spectral Density of Noise

$P_s(u, v)$ = Power Spectral Density of un-degraded image

*ii) Non Linear Filters*

With the non-linear filter, noise is removed without any attempts to explicitly identify it. Generally spatial filters remove noise to a reasonable extent but at the cost of blurring images which in turn makes the edges in pictures invisible. In recent years, a variety of nonlinear median type filters such as weighted median, rank conditioned rank selection, and relaxed median have been developed to overcome this drawback.

*Median Filter*

The Median filter is a nonlinear digital filtering technique, often used to remove noise. The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries. Note that if the window has an odd number of entries, then the median is simple to define: it is just the middle value after all the entries in the window are sorted numerically. For an even number of entries, there is more than one possible median. A major advantage of the median filter over linear filters is that the median filter can eliminate the effect of input noise values with extremely large magnitudes.

*2) Transform domain filtering*

The transform domain filtering can be subdivided into data adaptive and non-adaptive filters. Non-adaptive filters includes Wavelet domain.

*i) Wavelet Domain*

Noise reduction using wavelets is performed by first decomposing the noisy image into wavelet coefficients i.e. approximation and detail coefficients. Then, by selecting a proper thresholding value the detail coefficients are modified based on the thresholding function. Finally, the reconstructed image is obtained by applying the inverse wavelet transform on modified coefficients. Filtering operations in the wavelet domain can be subdivided into linear and nonlinear methods. Linear filters such as Wiener filter in the wavelet domain yield optimal results when the signal corruption can be modeled as a Gaussian process and the accuracy criterion is the mean square error (MSE).

The most investigated domain in denoising using Wavelet Transform is the non-linear coefficient thresholding based methods. The procedure exploits sparsity property of the wavelet transform and the fact that the Wavelet Transform maps white noise in the signal domain to white noise in the transform domain. Thus, while signal energy becomes more concentrated into fewer coefficients in the transform domain, noise energy does not. It is this important principle that enables the separation of signal from noise.

*ii) Data-Adaptive Filters*

Widely used Independent component analysis (ICA) is a statistical and computational technique for revealing hidden factors that underlie sets of random variables, measurements, or signals. ICA defines a generative model for the observed multivariate data, which is typically given as a large database of samples. In the independent component analysis method all the pixels in the image work independently which means they work in their own and they are not dependent on the neighbor’s pixel value. So it gives the best result while finding in the denoising techniques.

## IV. DISCUSSION

This paper gives fundamental idea about the image deblurring. It introduces about various methods for removing blur and noise from the image. The study shows that the deblurring algorithms depend on accurate modeling of noise. If the parameters not chosen properly, the deblurring process makes the images look worse than the original blurred image. The selection of denoising technique is application dependent. Performance of denoising algorithms is measured using quantitative performance measures such as peak signal-to-noise ratio and signal-to-noise ratio. Denoising procedure requires a priori knowledge of the noise.

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