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A COMPARATIVE STUDY OF VARIOUS IMAGE RESTORATION TECHNIQUES WITH DIFFERENT TYPES OF BLUR

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Abstract: In last few years there is a rapid growth of using images in various fields like computer science, medical science, security, data transmission etc. Images get corrupted due to various reasons during transmission. These corrupted images fail to show the exact feature of the image. To make these images clearly visible to all, these unwanted features that are added to the image must be removed by using some technique. There are different ways of adding noise or blur to the image as well as removing that noise and blur from the image. This review paper is related to different image restoration techniques and different techniques of adding noise or blur into the image.

Keywords*:* Blind Deconvolution, Blur, Lucy Richardson Algorithm, MSE(Mean Square Error), Noise, Non blind Deconvolution, PSF(Point Spread Function), PSNR (Peak Signal to Noise Ratio), Regularized Filtering. Weiner Filter.

1. Introduction

Image processing is the fast growing field in area of computer science and engineering. As technology advances, shows rapid growth in the field of images processing [1]. Digital Image Processing is the field of Signal Processing that uses computer algorithm to process digital image. These computer algorithms can be changed according to the requirement.

1.1 ***Blur:***

Blur can be defined as unwanted transition made into the original image due to various reasons like motion between camera and an object, atmospheric turbulence, out-of-focus of the camera, taking picture in fog etc. In blurring we reduce the edge content and make transition from one color to the other smoothly. If we are not able to perceive all the contents of the image clearly then it is said to be blurred. Following are the types of blur:

1.1.1 ***Motion Blur:*** Motion Blur occurs when there is a motion between the device taking picture and the object. It can occur in various forms like rotation, translation, sudden change of the scale, or the combination of these [2].

1.1.2 ***Average Blur:*** Average blur occurs on entire image. It can be distribute in horizontal and vertical direction and it can be circular averaging by radius R which can be calculated by the following formula:

$$R=\sqrt{g^2+f^2} \qquad (1)$$

Where, g is the horizontal size blurring direction and f is the vertical blurring size direction and R is the radius size of the circular averaging blurring [2].

1.1.3 ***Gaussian Blur:*** In this blur type, pixel weights are unequal. The blur is high at the center and decreased at the edges following bell shaped curve. If we want to control blur effect, we have to add Gaussian blur to an image. Gaussian blur depends on the size and Alfa. It is also known as Gaussian smoothing is a type of image-blurring filter that uses a Gaussian function (like normal distribution in statistics) for calculating the transformation to apply to each pixel in the image.
The equation of a Gaussian function in one dimension is:

$$G(x) = \frac{1}{\sqrt[2]{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}} \qquad (2)$$

In two dimensions, it is the product of two such Gaussians, one in each dimension.
Where, x is the distance from origin in horizontal axis. Y is the distance from origin in vertical axis.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (3)$$

1.1.4 ***Out-of-Focus Blur:*** Blurring can be caused when object in the image is outside the camera's depth of field sometime during the exposure. E.g. when a camera images a 3-D scene onto a 2-D imaging plane, some parts of the scene are in focus while other parts are not.

1.1.5 ***Atmospheric Turbulence Blur*:** Blur introduced by atmospheric turbulence depends on a variety of factors such as temperature, wind speed, exposure time.

Figure 1: Original image

Figure 2: Motion Blur having theta 11

Figure 3 : Gaussian blur with sigma=2

Figure 4: Average blur

Figure 5: Out-of-Focus blur

1.2 ***Noise:***

Noise in images can be defined as unwanted variation of brightness or color information. It can be visible as grains in the image. There are various sources of image noise. It can be produced at the time of capturing an image through camera or during transmission. Pixels in noisy image show different intensity value instead of true intensity value [3] .There exits various noise removal algorithm that are helpful for reduction of various types of noise depending upon the requirement.

1.2.1 ***Types of Noise:***

1) ***Impulse Noise (Salt and Pepper Noise):*** Impulse noise also referred as data drop-out-noise, intensity spikes, speckle or salt and pepper noise. This type of noise basically occurs during transmission. Black and white dots generally appear in the image in this type of noise. This arises in the image due to sharp and sudden changes of image signal. To add salt and pepper noise to an image, we need to add black and white pixels randomly into the image matrix. To remove such type of noise from the image 2 filters are used: median filter and morphological filter.

2) ***Gaussian Noise****:* It can also be referred as Normal Noise or Amplifier Noise. Gaussian noise follows probability distribution function like normal distribution function. The value this noise can take is Gaussian distributed.

3) ***Uniform Noise:*** It can also be referred as Quantization noise. Uniform noise is caused by quantizing the pixels of a sensed image to a number of discrete levels. It can be used to create any type of noise distribution.

4) ***Poisson Noise:*** It can also be referred as Shot Photon Noise. This noise arises when number of photons sensed by the sensor is not sufficient to provide detectable statistical information [4]. In this type of noise each pixel can have different noise values.

5) ***Speckle Noise****:* Speckle Noise is generally found in synthetic aperture radar images, medical images and satellite images. It can be expressed by using following formula:

$$J=I+n*I \qquad (4)$$

Where J is the speckle noise distribution image, I is the input image, n is the uniform noise image having mean 0 and variance v.

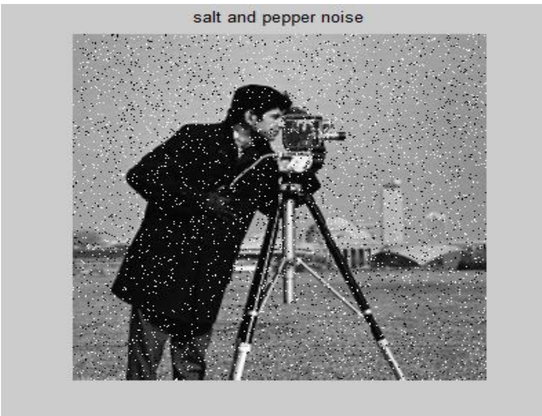

Figure 6 : Salt and Pepper noise with noise density,d=0.06

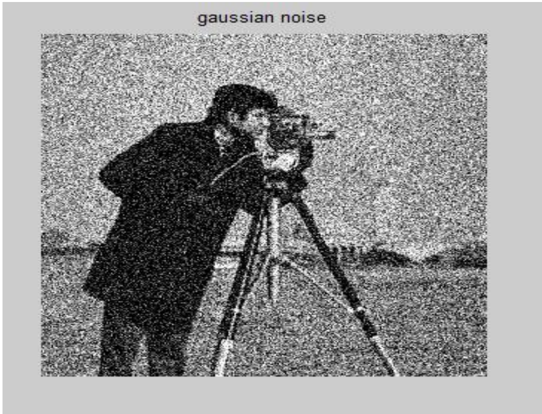

Figure 7: Gaussian noise with variance, v=0.05

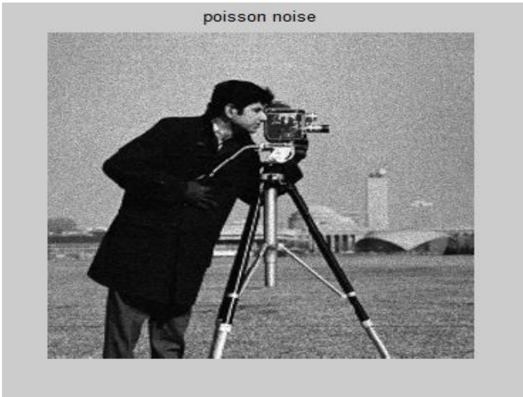

Figure 8: Poisson noise

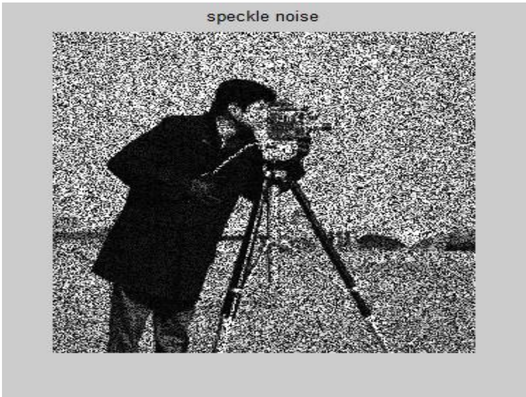

Figure 9: Speckle Noise with variance, v=0.0

Vol.3 Issue 11, Pg.: 54-60
November 2015

2. Image Restoration

Image Restoration is a process of recovering a original image from the degraded image which has been blurred due to various factors such as atmospheric turbulence, camera shake, motion between object and camera, foggy image etc. In the initial step of image restoration firstly a blur or noise is added into the image and then restore that blurry image by using suitable technique. There are different types of noise that can be added into the image such as salt and pepper noise also known as impulse noise, Gaussian noise etc. Different types of blur that can be added into the image are Gaussian blur, Motion blur, Out-of-Focus blur etc [5]. The process of blurring a digital image is known as Convolution Process and the process of recovering original image from the blurred image is known as Deconvolution process. Image Restoration technique is basically divided into 2 types:

2.1 Non- Blind Deconvolution Technique
2.2 Blind Deconvolution Technique

2.1 ***Non-Blind Deconvolution Technique:*** Deconvolution technique is a mathematical algorithm based process that is used to reverse the effects of convolution in an image. This technique is widely used in the field of image processing and signal processing [6]. In Deconvolution technique, restoration process has prior knowledge of the degradation process i.e. we have knowledge of PSF (Point Spread Function) . This degradation process first identifies the type of noise and then use inverse process to recover the original image from the degraded image.

2.1.1 Non-Blind Deconvolution Methods:

2.1.1.1 ***Lucy-Richardson Algorithm:*** The Lucy-Richardson algorithm can be used effectively when the point-spread function PSF (blurring operator) is known, but little or no information is available for the noise. It is an iterative procedure used for recovering latent image. The Richardson–Lucy Deconvolution algorithm has become popular in the fields of astronomy and medical imaging. Initially it was derived from Bayes Theorem in the early 1970’s by Richardson and Lucy. Following equation shows iterative execution of Lucy Richardson Algorithm [7]:

$$C_i = \Sigma_j \, p_{ij} \, u_j \tag{5}$$

Where, p_{ij} is the Point Spread function (PSF), u_j is the pixel value at location j in the latent image and c_i is the observed image value at pixel location i.
u_j can be solved iteratively by using following equation:

$$u_j = u_j^t \sum j \frac{c_i}{c_i} p_{ij} \tag{6}$$

Where,

$$C_i = \sum j u_j^t . p_{ij} \tag{7}$$

2.1.1.2 ***Weiner Filtering:*** Weiner Filtering is a non-blind Deconvolution technique that is used to restore the degraded image in the presence of PSF. It is helpful for removing noise as well as blur present into the image. It is a technique used to remove blur from the images that occur due to linear motion or unfocussed optic. It performs Deconvolution by inverse filtering (high pass filtering) as well as by compression operation (low pass filtering). Input to the Weiner Filter is degraded image corrupted through additive noise. It can be expressed through following equation:

$$F' = g^* (f+n) \tag{8}$$

Where, f is the original image, F’ is the estimated image, n is the noise and g is the Weiner’s Filter response.

2.1.1.3 ***Regularized Filtering****:* Regularized filtering is also a non-blind Deconvolution technique especially used for digital images for the removal of noise. This technique can be applied when limited information about the Point Spread Function (PSF) is known and constraints like smoothness is applied on the image. Regularized Filtering provides similar results as Weiner Filter but in Regularized Filtering we need little information about the blur or noise kernel function. This technique can be applied by constrained least square restoration algorithm that uses regularized filter.

2.2 ***Blind Deconvolution Technique*:** In this technique we restore an image without having prior knowledge of degradation process i.e. we have no knowledge of PSF (Point Spread Function). Blind Deconvolution is a technique of restoration of a degraded/ blurred image without having any knowledge of blur kernel or PSF(Point Spread Function) of an image. A kernel is a mask in the form of small matrix used to blur an image. This small matrix is known as Convolution Matrix. In this technique of restoration, blur kernel is unknown that is why it is known as 'Blind'. In the absence of any priori information about the imagery system and the true image, this estimation is normally done by trial and error experimentation, until an acceptable restored image quality is obtained [8]. Deconvolution is a technique to sharpen or deblur a blurry image, and collectively it is known as Blind Deconvolution Technique. A kernel is a 2D matrix that is used to blur an image also known as Convolution Matrix. It can be represented as:

$$Y=k*X+n \qquad (9)$$

Where, X is the input gray image. Y is the degraded image. K is the kernel or convolution matrix that is added with the input image X to transform it into the blurry image called Y. * is the convolution operator.

The goal of Blind Deconvolution is to inverse the above process and to recover both X and k [9]. This technique restores the blurry image by calculating PSF of the degradation by using three techniques and chooses the one that provides better restoration result. Techniques are:

1. Undersized PSF.
2. Oversized PSF.
3. INIT PSF

2.3 Degradation Model:

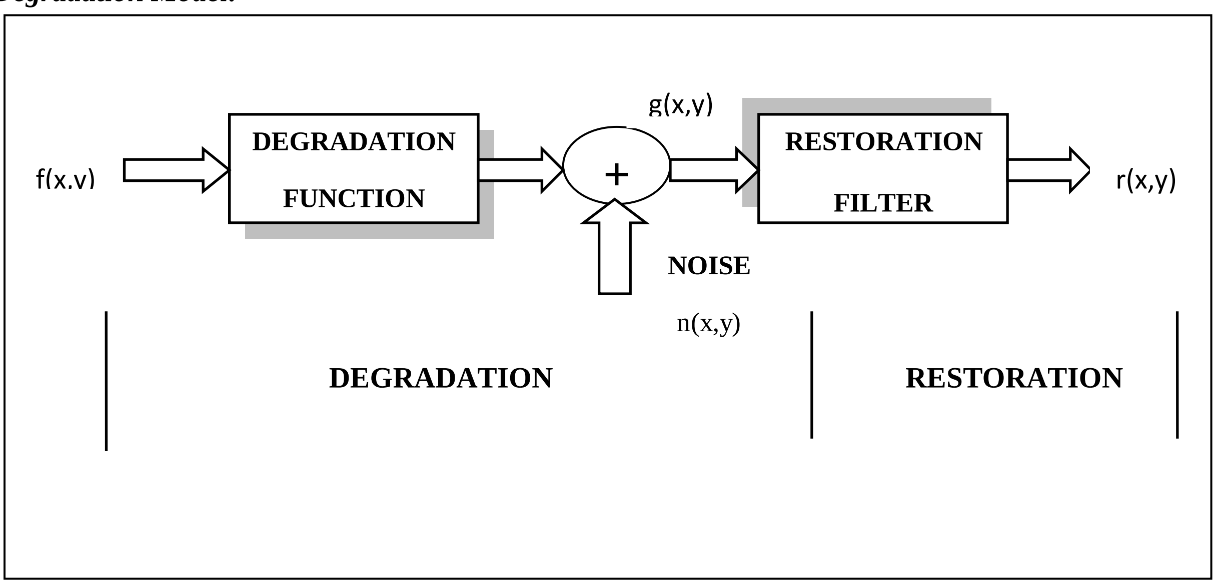

Figure 10: Degradation Model/ Restoration Model

Figure 10s shows Degradation and Restoration Model of the process. f(x,y) is the input 2-D image. After adding noise n(x,y) into the input image f(x,y) we get degraded image g(x,y). By applying Image Restoration Technique on the degraded image g(x,y) we get the restored image r(x,y).

It can clearly be defined by using eq (10):

$$g(x,y) = h(x,y) * f(x,y) + n(x,y) \tag{10}$$

Where h(x,y) is the function that causes distortion and n(x,y) is the noise. The symbol * represents convolution.

3. Conclusion

There exist various techniques for removing noise and blur from the images depending upon the type of blur and noise added into the image. Each algorithm have different results and the performance of these algorithm is measured in terms of perception of human eye, PSNR (Peak Signal to Noise Ratio), MSE (Mean Square Error). The mail goal of Image Restoration Algorithm is to get the clear image. Higher the value of PSNR, more clear will be the image quality and need to minimize MSE.

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