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# A Survey on Image Restoration

Jitendra Suthar[1], Rajendra Purohit[2]
Research Scholar[1] ,Associate Professor [2]
Department of Computer Science,
JIET, Jodhpur

*Abstract*: **Images in the real world are subject to various forms of degradation during image capture, acquisition, storage, transmission and reproduction. Images are everywhere in our daily life. This is not only because image is a widely used medium of communications, but also because it is an easy and compact way to represent the physical world. Processing of digital images with the help of digital computers known as Digital Image Processing. One of the most applicable areas in Image Processing methods is to enhance the pictorial information for human perception. Image restoration is a method to clearing the degraded image to obtain the original image. For years researchers have been working in developing new techniques that can restore the original image from degraded image. The aim of this paper is to demonstrate the different types of techniques for image Restorations.**

**Index terms:** Blur, Deblurring, Image Restoration

## I. INTRODUCTION

Image deblurring is an old problem in the field of image processing, one that continues to accumulate attention from academics and businesses alike. Its application areas are observed in many different real-world problems and work as an easy way to visualize examples of a larger range of inverse problems in many fields [1]. Image deblurring attempt to take a blurry image and restore it to its original form algorithmically. When deblurring images, a mathematical description of how it was blurred is very important to boost up the effectiveness of the deblurring process. In real-world captured photos, we do not have the luxury of knowing the mathematical function by which the image was blurred. However, there exist methods to approximate how blur occurred. There are many different sources of blur in a photograph, such as camera shake, long exposure times, motion blur and atmospheric turbulence. Even a relatively small amount of any of these effects is enough to distortion of a real world photos. Every picture taken comes out blurry to some degree by any source of blur, image deblurring is fundamental in making pictures sharp, clear and useful in real world [2].

### *A. What is image restoration?*

Due to deficiency in the image development process and the imaging device, the observed image often represents the distorted version of the original image. The corrections of these deficiency are mandatory in many of the upcoming image processing and vision tasks. Different types of degradations exist in the nature which includes noise, blur, geometrical degradations, illuminations etc. The images were degraded versions of the original images due to substandard imaging environment, spinning and the tumbling of the spacecraft. To retrieve the meaningful information from the degraded images, image restoration techniques were used. It is not a surprise to see that restoration of digital image is used in astronomical imaging even today. Ground based imaging systems were also affected by blur due to change in refractive index of the atmosphere [3].

All natural images when displayed have gone through some sort of degradation:

- During processing mode degradations may also takes place.
- The degradation may occur when camera is in the acquisition mode.
- The degradation may occur during display mode.

*B. How much image can be restored?*

It depends on how much we know about the original image, information contains in the original image how much the image is degraded, reasons behind the degradations and how accurate our degradation models are and with what accuracy it can be implemented.

*C. Image Degradation Model*

The resultant degraded image g(x, y) is obtained by applying the degradation operator H onto the input image f(x, y) along with the additive noise η(x, y). The degradation Model is mathematically expressed as,

$$g(x,y) = H[f(x,y)] + \eta(x,y) \quad (1)$$

The aim of image restoration is try to estimate f(x, y) from the observed image g(x, y) using the known value of H [5, 6]. The overall degradation and restoration model is shown in the Figure 1. The operator H may be linear or nonlinear.

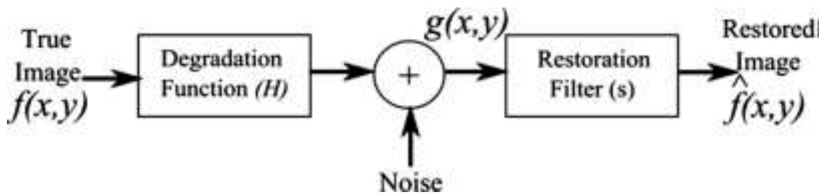


Figure 1: Image degradation restoration model

Mostly, it is assumed to be linear which satisfies the principles of superposition and homogeneity [7]. The operator H is also considered to be space invariant or position invariant. An operator is said to be space invariant if the response at any point depends on the value at that point but not on the position of the point and is defined mathematically as,

$$H[f(x-\alpha, y-\beta)] = g(x-\alpha, y-\beta) \quad (2)$$

for all f(x, y) and any α and β. In terms of impulse function f(x, y) is expressed as,

$$f(x,\ y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(\alpha,\beta)\delta(x-\alpha, y-\beta)d\alpha d\beta \quad (3)$$

Substituting 3 in 1 we get the observed image g(x, y) and is expressed as,

$$g(x,\ y) = H\left[\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(\alpha,\beta)\delta(x-\alpha, y-\beta)d\alpha d\beta\right] + \eta(x,y) \quad (4)$$

As f (α, β) is independent of x and y, using the linearity property, the g(x, y) can be expressed as,

$$g(x,\ y) = H\left[\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(\alpha,\beta)h(x,\alpha,y,\beta)d\alpha d\beta\right] + \eta(x,y) \quad (5)$$

where h(x, α, y, β) = H [δ(x − α, y − β)] is called point spread function in the optics. The expression given in 5 is called the Fredholm integral of the first kind. Since operator H is spatial invariant we have,

$$H[\delta(x-\alpha, y-\beta)] = h(x-\alpha, y-\beta) \quad (6)$$

and the degraded image is given as,

$$g(x,\ y) = H\left[\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(\alpha,\beta)h(x-\ \alpha, y-\ \beta)d\alpha d\beta\right] + \eta(x,y) \qquad (7)$$

This expression is called the convolution integral in the continuous variable.

*D. Categories of Image Restoration Techniques:*

In real images, blurring artefacts appear quite frequently. Thus deblurring, the task of making a blurred image sharp again, is a very important problem in image processing. The deblurring problem can be posed in the spatially variant as well as in the spatially invariant setting. Due to the strong relation of blurring to convolution, deblurring is often just called deconvolution, even in the spatially variant case.

There are mainly two different kinds of deblurring, depending on how much information is assumed to be known. Figure 2 shows both variants: non-blind and blind deblurring. [4]

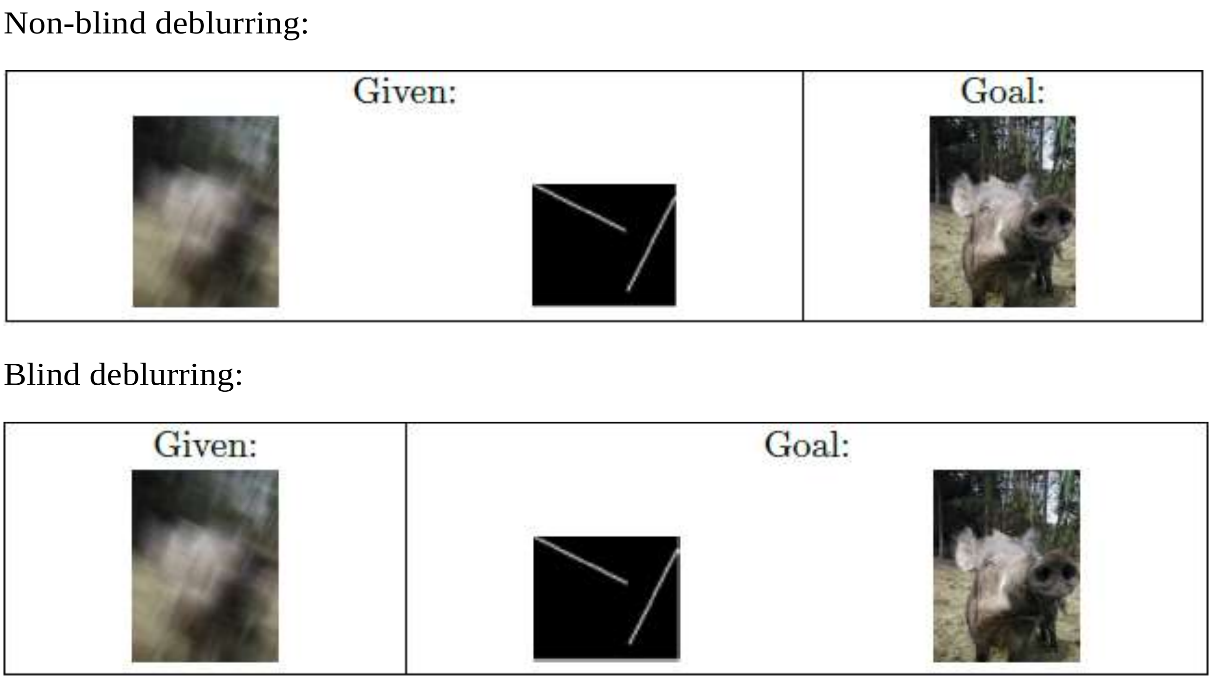


Figure 2: Non-blind and blind deblurring [4]

In non-blind deblurring we assume that the observed image and the PSF is known. So the input of a non-blind deblurring algorithm would be a blurred image as well as the corresponding PSF, the output would be the unblurred image. Whereas in the case of blind deblurring, we only have a blurred image and we are searching for the corresponding PSF and the unblurred image.

*E. Applications of Image Restoration:*

Applications in the field of image restoration are:

- The foremost application of image restoration in the engineering field was in the area of astronomical imaging system. Extraterrestrial observations of the the planets and Earth were degraded by Gaussian blur and motion blur as a result of slow camera shutter speeds relative to rapid spacecraft motion. The astronomical imaging degradation problem is usually characterized by Gaussian noise and Poisson noise etc.

- Image restoration has played a very important role in the area of medical imaging. Restoration has been used for filtering of Poisson distributed film-grain noise in digital angiographic images and chest X-rays, mammograms, and the removal of additive noise in Magnetic resonance Imaging.
- Another important application of restoration technique is to recover deteriorated and aging films. The motion image restoration is usually associated with digital techniques are used to colorize black and white films and also to remove dust and scratches from old movies.
- Digital image restoration is also used in the field of image and video coding. As techniques are developed to reduce the bit rates of coded images, and to improve coding efficiency. After decompression of coded image for restoring purpose, restoration operation is performed as a post-processing step.
- Digital image recovery has also been used to restore blurred X-ray images of aircraft wings to improve aeronautical federal control procedures. It is for the recovery of the motion induced in the present frame or composite effects, and is generally used, restoring television images blurred uniformly.

## II. TYPES OF BLUR

Blurs are treated as low pass filters which smoothes out the unexpected changes in the gray level of an image. There are different analytical models used in image processing to represent the shift invariant degradation model. The blur also decreases the contrast of image by averaging the value of pixels. Any real-world image may be blurred in various ways including motion (camera shake) blur, atmospheric turbulence blur, out-of-focus blur etc.

The characteristics of some common blurs are described below

### 1. *Linear Motion Blur*

This blur results either due to object or camera motion during exposure. It is governed by 2 parameter, namely the length of motion (L) and the angle of motion (θ). When a scene to be imaged translates with a relative velocity V in respect to the camera, the blur length L in pixels is $L = V\,T_{exposure}$ where, $T_{exposure}$ is the time duration of the exposure. The expression for PSF of the motion blur is given as,

$$h(x,y) = \begin{cases} \frac{1}{L}, & \text{if } 0 \le |x| \le L\cos\theta;\ y = L\sin\theta, \\ 0, & otherwise \end{cases} \quad (8)$$

When the blur angle is zero i.e. θ = 0, it is called as horizontal motion blur. The discrete version of PSF is given by,

$$h\,(m,n;\,L) = \begin{cases} \frac{1}{L} & \text{if } m = 0, |n| \le \left|\frac{L-1}{2}\right| \\ \frac{1}{2L}\left\{(L-1) - 2\left|\frac{L-1}{2}\right|\right\} & \text{if } m = 0, |n| \le \left|\frac{L-1}{2}\right| \\ 0 & elsewhere \end{cases} \quad (9)$$

### 2. *Out of Focus Blur*

When a three dimensional scene is projected onto a two dimensional plane, some part of the scene may not be focused properly. For a circular aperture camera, the projected image of a point source is a small disk which is known as circle of confusion. The strength of defocus depends on the length of focal and distance between the object and camera. The PSF of the out-of-focus blur is given as,

$$h(x,y) = \begin{cases} \frac{1}{\pi R^2}, & if\sqrt{x^2+y^2} \le R, \\ 0, & otherwise \end{cases} \quad (10)$$

where R is the radius.

*3. Atmospheric Turbulence Blur*

This blur occurs due to turbulent atmosphere of the earth. It is mainly encountered in remote sensing applications because of variations in the wind velocity. This leads to change in the refractive index of a layer which distorts the image to be observed. It is effectively modelled as a Gaussian Point Spread Function (PSF) with standard deviation σ. The PSF of the turbulence blur is given as,

$$h(x,\ y) = \frac{1}{2\pi\sigma^2}\, exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \qquad (11)$$

Here σ decides the severity of the blur. In this thesis, the above blurs are considered independently and attempts have been made to restore the images from the corresponding degraded images.

## III. IMAGE RESTORATION TECHNIQUES

This section assumes that PSF is known prior to restoration. A number of methods exist to remove the blur from the observed image g (m, n) using a linear filter. The restored image f from a given blurred image is given by

$$\mathrm{f}\,(\mathrm{m,n}) = \mathrm{g}\,(\mathrm{m,n}) * \mathrm{h}\,(\mathrm{m,n})$$

$$= \sum_{k=0}^{m-1}\sum_{l=0}^{n-1} g\ (k,l)h\ (m-\ k, n-\ l) \qquad (12)$$

where $*$ denotes the deconvolution which represents the inverse of the convolution. In the frequency domain, this can be expressed as

$$\mathrm{F}\,(\mathrm{u,v}) = \mathrm{G}\,(\mathrm{u,v})\,\mathrm{H}\,(\mathrm{u,v}) \qquad (13)$$

where F denotes the estimated image in spectral domain. G (u, v) and H (u, v) are the blurred image and PSF in frequency domain respectively.

*1) Inverse Filtering*

Inverse filter uses the inverse of the PSF as an impulse response. It is difficult to implement the filter in the image domain. An estimate of the transform of the original image is obtained by dividing the transform of the degraded image G (u, v) by the degradation function. The division is performed on individual elements. Using the value of G (u, v)

$$\hat{F}\,(\mathrm{u,v}) = \mathrm{F}\,(\mathrm{u,v}) + \frac{N(u,v)}{H(u,v)} \qquad (14)$$

The inverse filter requires PSF prior to restoration. It gives good results if there is no noise. When there is no noise, second term of the above equation vanishes and the restored image is identical to the original image. The values of H (u, v) is zero at some selected frequencies. When the noise is associated with the image, noise is amplified at those frequencies and the result is dominated by the amplified noise.

**2) Wiener Filtering**

Wiener filtering is most useful technique for image deblurring. The wiener filter has a good performance to reduce the blur effect in images caused by unfocussed optics or linear motion. In real life the corrupted image is a result of poor sampling. Usually individual pixel in the image should consist intensity value for a single stationary point in front of the capturing device like as camera. Unfortunately, if the shutter speed is very slow or camera is moved, a given pixel will be a mixture of intensities from points along the line of the camera's motion [10, 11].

**3) Lucy-Richardson Deconvolution**

This algorithm has been independently proposed by Lucy [8] and Richardson [9]. The L-R algorithm is an iterative technique that maximizes a Poisson statistics image model likelihood function. The L-R algorithm performs the following steps.

1. An initial approximation of the restored image $\widehat{f_0}$ is made. Typically, the observed image g is taken as $\widehat{f_0}$
2. The approximation is convolved with the PSF as,

$$\varphi_n = h * \hat{f}_n \tag{15}$$

3. A correction factor is calculated depending on the ratio of the blurred image and output of the last step as,

$$\phi_n = \overleftarrow{h} * \frac{g}{\varphi_n} \tag{16}$$

where h is the PSF in reverse order.

4. The new restored image is given by

$$\hat{f}_{n+1} = \hat{f}_n \cdot \phi_n \tag{17}$$

where · denotes the pixel by pixel multiplication in spatial domain steps 2 to 4 are iteratively performed till an acceptable image quality is obtained.

#### 4) Blind Image Restoration Techniques

Blind image deconvolution problem has some important characteristics [9] which are given as,

1. The true image and PSF must be irreducible. An irreducible signal is one which cannot be exactly expressed as the convolution of two or more component signals.
2. The restored image is not the exact true image, rather it is a scaled, shifted version of the original image. That is,

$$\hat{f}(x,y) = K\,f\,(x - D_x, y - D_y) \tag{18}$$

where $\hat{f}(x, y)$ is the estimated image and K, $D_x$, $D_y$ are the real constants.

3. The solution of the problem is not unique.
4. There is always a poor compromise between the complexity, convergence and portability of the algorithms used for blind deconvolution.

## IV. CONCLUSION

Image Restoration is the most important field of image processing, now a days it is very important step for recover the images which corrupted by any source of blur. Basically there are three types of blur linear motion blur, out of focus blur and atmospheric turbulence blur, so any real time captured image is corrupted by these three causes. First technique for restoration is Inverse Filter disadvantage of this is information about blurring filter must be already known and noise is also not present in input image. Another technique is Wiener Filter it has some advantage over inverse filter that is it performs an optimal trade-off between noise smoothing and inverse filtering because it eliminate the additive noise and inverts the effect of blurring concurrently. It also have some disadvantage these are as follows it is spatially invariant and produced results are often too blurred. The Lucy-Richardson algorithm, or Lucy deconvolution, it has advantage above Wiener Filter these are as follows, it is Non-blind deconvolution based on probabilistic model, it yields maximum likelihood solution under Poisson noise model and it is standard method used widely in Astronomy, Hubble space telescope. So Lucy-Richardson algorithm is the best algorithm for deblurring of blurred images in non- blind techniques.

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