A Performance Based Analysis of Various Image Deblurring Techniques

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Abstract

This paper presents the study of various Image Restoration techniques as Blind de-convolution algorithm, Regularized filter, Lucy Richardson de-convolution algorithm and Weiner Filter, which will be used to recover the clear image from the Gaussian Blurred Images with the information of Degradation Function (Point Spread Function), and then the reconstructed image from these four de-convolution methods will be compared to the original image by using Peak-to-Noise Ratio (PSNR) value. This paper attempts to choose the base technique for deblurring degraded image.

Keywords: Gaussian Blur, PSF, Deblurring, Techniques, Mean Square Error, Peak-to-signal-noise ratio.

I. Introduction

Image restoration is a field of Image processing which deals with recovering an original and sharp image from a degraded image using a mathematical degradation and restoration model. It is the task of minimizing the degradation in an image i.e. recovering an image, which has been degraded due to presence of noise, and the original scene is not clear. Images are captured and produced to record or display useful information or details. Due to flaws in the imaging and capturing process, the recorded image always represents a degraded version of the original scene [1]. The undoing of these imperfections is critical to many of the successive image processing tasks. There exists a huge range of different degradations, which should be taken into account, for example noise, geometrical degradations, illumination and color imperfections and blur[2]. The area of image restoration (sometimes called image deblurring or image de-convolution) is concerned with the reconstruction or estimation of the uncorrupted image from a blurred noisy image. However, it is very essential process in the image processing to restore the image by using the image processing techniques to easily understand the image without any error.

Image restoration assures good insights of image when it is subjected to further techniques of image processing. Due to certain imperfections in the imaging or capturing process, the captured image is a degrade version of the original scene. The imperfections in the images captured can be due to camera mis-focus, motion blurs i.e. degradation due to relative motion of camera and the scene being captured, the image captured is degraded [9].

Blur

Blurring is a form of reduction of bandwidth of an ideal image owing to the imperfect image formation process. It can be generating by the relative motion between camera and the original scene, or by an optical network that is out of focus. In digital image various types of blur effects exist:
1. Average Blur
The Average Blur is one of the several tools that can be used to remove noise and specks in an image when the noise is present in an entire image. Averaging blurring can be distributed in horizontal and vertical direction and can be finding by circular averaging of radius $R$ that is calculated as:

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

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 average blurring [3].

2. Gaussian Blur
The Gaussian Blur effect is a filter that blends a specific number of pixels incrementally, following a bell-shaped curve [5]. Blurring is dense in the center and feathers at the edge. Apply Gaussian Blur filter to an image when we want more control over the blur effect [4].

3. Motion Blur
It occurs due to the relative motion between the object or scene and the camera during exposure. This effect is a filter that makes the image appear to be moving by adding blur in a specific direction. The motion can be controlled by angle or direction ($0$ to $360^\circ$ or $-90$ to $+90$) and by distance or intensity in pixels ($0$ to $999$) based on the software used [6].

4. Atmospheric Blur
It occurs due to the random variations in the reflective index of the medium between the object and the imaging system and it occurs in the imaging of astronomical objects.

5. Out of focus Blur
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. 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. An accurate model not only describes the diameter of the COC, but also intensity distribution within the COC [7].

II. Basic Model Of Image Restoration
The main objective of Image Restoration is to recover the original image from a degraded image, which is blurred by using degradation function as shown in figure (1), and figure (2).

In figure (1), the original image is first being degraded using a degradation function and the noise is added to the output of the degradation function. It is expressed as:

$$g(x, y) = h(x, y) * f(x, y) + n(x,y) \quad \text{(2)}$$

Where $g(x, y)$ is the degraded image, $h(x, y)$ is the spatial representation of degradation function, the symbol $*$ indicates the convolution, $f(x, y)$ represents the original image and $n(x, y)$ represents the additive noise.
In figure (2), the degraded image is then given to the restoration filter, which suppresses the noise to an extent to produce an image much likely to the original image. It can be expressed as:

\[ f'(x, y) = H \left( g(x, y) \right) \quad \ldots \ldots \text{(3)} \]

where \( f'(x, y) \) is the restored image, \( H' \) is the restoration function and \( g(x, y) \) is the degraded image.

### III. Related Literature Work

There are several researchers who have worked in the field of image restoration and proposed various techniques to overcome the issue of noisy image and image blurring, they are discussed below:

- **Gupta et.al in Feb 2011** proposed a method to restore images affected by motion blur by using three stages. In the first stage a comparison of two image restoration methods was carried out, namely wiener filter and blind de-convolution. To improve the quality of image wavelet based image fusion was proposed in second stage. Finally, in the third stage the fused images are again restored using a low pass filter. The effectiveness of the methods was compared using parameters like RMSE and PSNR. The work show that Wiener filter followed by Wavelet based Image Fusion provided the better results than iterative blind de-convolution method followed by Wavelet based Image Fusion.
• **Kaur et al. in 2012** proposed a novel approach for image restoration by removing the blur degradation by using blind and non-blind techniques. In this approach the three different image formats viz. .jpg (Joint Photographic Experts Group), .png (Portable Network Graphics) and .tif (Tag Index Format) are considered for analyzing the various image restoration techniques like De-convolution using Lucy Richardson Algorithm, De-convolution using Weiner Filter (DWF), De-convolution using Regularized Filter (DRF) and Blind Image De-convolution algorithm (BID). In this approach the analysis is done based on various performance metrics like PSNR (Peak signal to noise ratio), MSE (Mean square Error), and RMSE (Root Mean Square Error).

• **Khare et al. in 2011** compared the performance of various image restoration techniques like Richardson Lucy algorithm, Wiener Filter, Neural Network approach, based on PSNR (Peak Signal to Noise Ratio). They are widely used for restoration of image in various fields of applications, such as medical imaging, astronomical imaging, remote sensing, microscopy imaging, photography deblurring, and forensic science, etc. Often the benefits of improving image quality to the maximum possible extent for outweigh the cost and complexity of the restoration algorithms involved.

• **Salem et al. in 2011** proposed a four types of techniques of deblurring image as Wiener filter, Regularized filter, Lucy Richardson De-convolution algorithm and Blind de-convolution algorithm with an information of the Point Spread Function (PSF) corrupted blurred image with different values of length and theta and then corrupted by Gaussian noise for image restoration. The same method is applied to the remote sensing image and they are compared with one another. So as to choose the base technique for restored or deblurring image. In this method the study of restored Motion blurred image with no any information about the Point Spread Function (PSF) by using same four techniques after execute the guess of the PSF, the number of iterations and the weight threshold of it. To choose the base guesses for restored or deblurring image of this techniques.

• **Kalyankar et al. in 2010** proposed an approach to restore the Gaussian Blurred images by using four types of techniques of deblurring image as Regularized filter, Weiner filter, Lucy Richardson de-convolution algorithm, Blind de-convolution algorithm with an information of the Point spread function (PSF) corrupted blurred image with different values of size and Theta and then corrupted by Gaussian noise. He also attempted to restore the Gaussian blurred image without any information about the Point Spread Function (PSF).

• **Anamika Maurya in 2014** proposed a novel approach for image restoration of the degraded image that had blurred during image acquisition process and restore them by using different types of filtering techniques like Wiener filter, Lucy Richardson algorithm, Blind de-convolution and also described the weakness and strength of each approach that are identified.

• **Khamitkar S.D in 2010** presented a technique for restoring or deblurring the image and attempted the restoration on Gaussian Blurred image with and without any knowledge of PSF by using four techniques like Regularized filter, Lucy Richardson algorithm, Weiner Filter and Blind Convolution method by attempted the number of iterations and weight threshold of the techniques.
IV. Restoration Techniques

Image restoration techniques are the methods, which attempt the inversion of some degrading process. Based on knowledge of degradation function image restoration techniques can be divided into two categories: blind (deterministic) and non-blind (stochastic) techniques. An image restoration technique is known as deterministic model if there is having any prior knowledge about the degradation. If it is not known then the stochastic method of image restoration has to be employed. Based on knowledge about Point Spread Function (PSF), image restoration techniques categorized as follows:

![Diagram of Image Restoration Techniques]

**Fig (3)- Classification of Image restoration techniques**

1. **Blind Image Restoration**

   This technique allows the reconstruction of the original images even when we have very little or no knowledge about PSF.

2. **Non-Blind Restoration**

   This technique helps in the reconstruction of original images from degraded images when we have knowledge about PSF.

**PSF-** **Point spread function (PSF) is the degree to which an optical system blurs (spreads) a point of light [10].** The PSF is the inverse Fourier Transform of Optical Transform Function (OTF) in the frequency domain. The OTF describes the response of a linear, position-invariant system to an impulse. OTF is the Fourier transfer of the point (PSF) [7].
This paper attempts the inversion of blurring effects by applying four types of deblurring filters:

1) **Blind De-convolution Method**

De-convolution is a signal processing operation that, ideally, unravels the effect of convolution performed by a linear time-invariant system operating on an input signal. In de-convolution, the output signal and the system are both known and the requirement is to reconstruct what the input signal must have been. In Blind De-convolution, only the output signal is known (both the system and the input signal are unknown), and the requirement is to find the input signal and the system itself. However, it needs higher Computation, so it is lengthy process for real time systems.

2) **De-convolution using Weiner Filter deblurring method**

Weiner Filter is a standard image restoration approach proposed by N.Weiner that incorporates both the degradation function and statistical characteristic of noise into the restoration function. Weiner Filtering is also a non-Blind technique for reconstructing the degraded image in the presence of known PSF. It removes or reduces to some extent the additive noise and inverts the blurring simultaneously. Weiner Filter not only performs the de-convolution by inverse filtering (high pass filtering) but also removes the noise with compression operation (low pass filtering). It compares with an estimation of the noiseless image or desired image. The input to a Weiner filter is a degraded image corrupted by additive noise [2]. The output image is calculated by means of a filter using the following expression i.e.

\[ f = g \ast (f + n) \] 

Weiner De-convolution can be used effectively when the frequency characteristics of the image and additive noise are known, to at least some degree. In the absence of noise, the Weiner Filter reduces to the ideal inverse Filter.

3) **De-convolution Using Regularized Filter Deblurring Method**

Regularized filtering is used in a better way when constraints like smoothness are applied on the recovered image and very less information is known about the additive noise. The blurred and noisy image is regained by a constrained least square restoration algorithm that uses a regularized filter. Regularized restoration provides almost similar results as the Weiner filtering but viewpoint of both the filtering techniques are different. In regularized filtering less previous information is required to apply restoration. The regularized Filter is frequently chosen to be a discrete Laplacian. This filter can be understood as an approximation of a Weiner Filter.

4) **De-convolution using Lucy Richardson Algorithm**

DLR is a non-blind technique of image restoration, used to restore a degraded image that has been blurred by a known PSF. It is an interactive procedure in which the pixels of the observed image are represented using the PSF and the latent image as follows [11]:

\[ d_i = \sum p_{ij} u_j \] 

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In equation (5), \( d_i \) is the observed value at pixel position, \( p_{ij} \) is the PSF, the fraction of light coming from true location, \( j \) that is observed at position, \( u_j \) is the latent image pixel value at location. The main objective is to compute the most likely, \( u_j \) in the presence of observed \( d_i \) and known PSF \( p_{ij} \) as follows:

\[
 u_j^{(t+1)} = u_j^{(t)} \sum_i d_i p_{ij} \quad \ldots \quad (6)
\]

\[
 c_i = \sum p_{ij} u_j^{(t)} \quad \ldots \quad (7)
\]

VI. Experiments

(i) Testing Procedure

The deblurring was implemented on Gaussian blurred images with the help of PSF function corrupted on images. Four types of deblurring methods are implemented: Blind de-convolution algorithm, Regularized Filter, Weiner Filter, and Lucy Richardson algorithm method, by applying Gaussian blur on the image with the known PSF.

(ii) Mathematical Analysis

In this section, the comparison has been attempted between four existing deblurring techniques (blind de-convolution, regularized filter, and Weiner filter, Lucy Richardson filter) to assess the performance of the de-convolution filters for the removal of Gaussian Blur. The comparison between various image deblurring techniques has been done on the basis of two error metrics; Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR).

(a) Mean Square Error

The mean square error is the cumulative squared error between the deblurred image and original image, which is expressed as:

\[
 \text{MSE} = \frac{\sum_{m,n} (I_1(m,n) - I_2(m,n))^2}{M \times N} \quad \ldots \quad (8)
\]

Where \( I_1(m,n) \) represents the original image, \( I_2(m,n) \) is the reconstructed image and \( M, N \) are the dimensions of the images.

(b) Peak Signal-to-Noise Ratio

PSNR is most commonly used to measure the quality of reconstruction of blurred images that was deblurred using various image restoration techniques. The signal in this case is the original image, and the noise is the error introduced by degradation function. The signal in this case is the original image, and the noise is the error introduced by degradation function. PSNR is an approximation to human perception of reconstruction quality. It can be expressed as:

\[
 \text{PSNR} = 10 \log_{10} \left( \frac{255^2}{\text{MSE}} \right) \quad \ldots \quad (9)
\]

The higher value of PSNR in the restored image, the better is its quality.

(iii) Results

The performance results of deblurring operations were implemented on the Gaussian blurred image with the information of PSF applied on the image. The image was filtered to remove this known amount of blur using Blind de-convolution algorithm,
Regularized Filter, Weiner filter, Lucy Richardson filter and compare the results produced by each of them. The comparative analysis has been presented based on different values of Mean Square Error (MSE) and PSNR (Peak Signal-to-Noise Ratio) which is shown in the Table (1).

### Table (1) Comparison Table

<table>
<thead>
<tr>
<th>Deblurring Method</th>
<th>Mean Square Error (MSE)</th>
<th>Peak Signal to Noise Ratio (PSNR) db</th>
<th>Performance based on PSNR values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind De-convolution</td>
<td>5.0978</td>
<td>44.9873</td>
<td>VERY EFFICIENT</td>
</tr>
<tr>
<td>Regularized Filter</td>
<td>6.3019</td>
<td>43.9846</td>
<td>EFFICIENT</td>
</tr>
<tr>
<td>Weiner Filter</td>
<td>9.2650</td>
<td>41.4397</td>
<td>WORST</td>
</tr>
<tr>
<td>Lucy Richardson Filter</td>
<td>6.3270</td>
<td>43.9383</td>
<td>EFFICIENT</td>
</tr>
</tbody>
</table>

Fig (4) - Deblurring Gaussian Blurred image with the known PSF

### VII. Conclusion

In this paper, the comparative study undertaken on the evaluation performance of different types of de-convolution filters, applied on the Gaussian blurred image of size 200X200 with the known PSF. After the comparison of performance metrics of deblurred images, Blind De-convolution algorithm produced the best result as compared to other methods of de-convolution with the MSE value of 5.0978 and PSNR value of 44.9873 as shown in the Table (1).
VIII. References:


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