Evaluation of Image Deblurring Techniques

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3 authors:

Sudha Yadav
Amity University

Charu Jain
Sharda University

Aarti Chugh
Amity University, Gurgaon, Haryana

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Sudha Yadav
Department of computer science Amity University, Haryana

Charu jain
Assistant Professor
Department of computer science Amity University, Haryana

Aarti chugh
Assistant Professor
Department of computer Science Amity University, Haryana

ABSTRACT
Degradation of images is one of the major problems in image processing. Blur in images is an unwanted reduction in bandwidth which degrades the image quality and it is difficult to avoid. Blur occur due to atmospheric turbulence as well as improper setting of camera. Along with blur effects, noise also corrupts the captured image. Restoration of image is a technique to get rid of the blur from the degraded image and recover the original image. Blur can be of various types like Gaussian blur, motion blur etc. Now a day's there are various different techniques and methods have been proposed to deblur a degraded image. For specific types of blur there are specific methods to remove it. Image restoration has applications in various different-different fields like medical imaging, forensic science, and astronomy. In this paper, we will discuss various image deblurring techniques and their analysis of performance.

Keywords
Deconvolution, Degradation model, Point spread function (PSF), Peak signal to noise ratio (PSNR).

1. INTRODUCTION
Research in image deblurring is going on since a long time ago. A huge part of image processing field is committed to image deblurring. Restoration process of images focus on reconstruction of proper images from the blurred one. As noise also corrupts the image so we need to perform image denoising. Image denoising is also a part of deblurring procedure. There are three main types of blur in digital image:

- Average blur: Average blur can be scattered in both directions (Horizontal, Vertical). Average filter will remove this type of blur and it is useful when noise affects the whole image.
- Gaussian blur: Blur which is simulated by Gaussian function. Effect of gaussian blur produced through a filter that follows a bell-shaped curve by unifying a definite no. of pixels incrementally. Such type of blurring is impenetrable in the centre and at the edge side blur will fluffs.
- Motion blur: Motion blur occurs due to comparative motion between the camera and the scene. Motion blur effects can be simulated in an image using motion filter in a specific direction then the resulted image will appear to be moving [2].

Image blurring based on degradation model. According to degradation model representing by fig.1, original image will convolve with degraded function i.e. point spread function using convolution operator which work like a multiplication operator. Then we get degraded image or blurred image. Noise also present into degraded image.

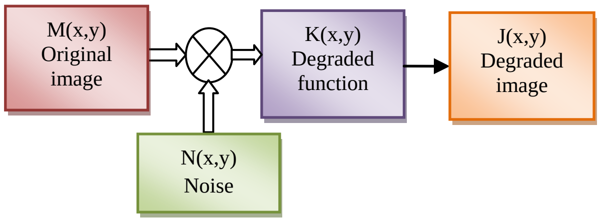

Fig. 1: Image Degradation Model

The blurred image can be represented by this following equation (1) which is based on degradation model:

$$J(x,y)=M(x,y)*K(x,y)+N(x,y) \qquad (1)$$

Here j(x,y) is degraded image, k(x,y) represents original uncorruped image, m(x,y) represents blur kernel that caused the degradation, n(x,y) represents noise[2,8].

Image representation of equation (1) showing how an image get blurred:

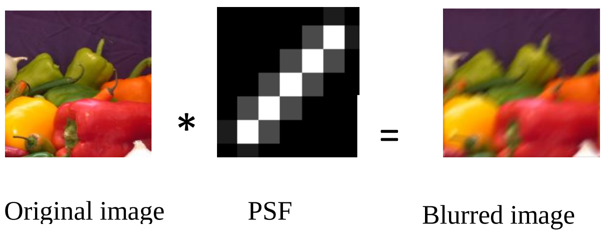

Fig. 2: Process showing how an image gets blurred

2. DEBLURRING TECHNIQUES
There are various image deblurring techniques in image processing. Out of which four basic techniques are classified as:

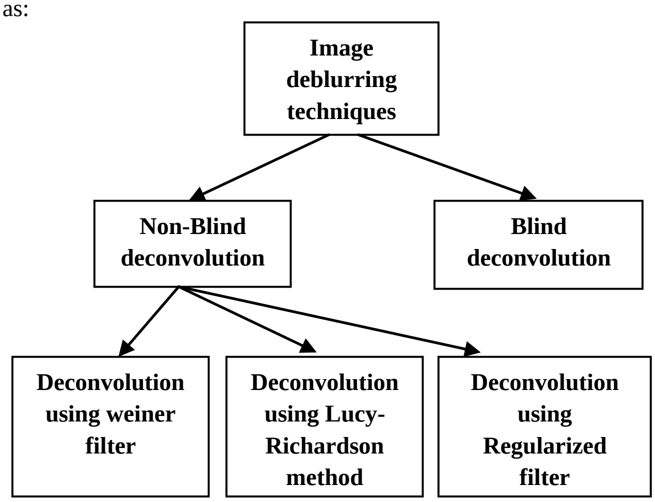

Fig. 3: Classification of image deblurring techniques

2.1 Non-Blind Deconvolution

In this technique, we require the prior knowledge about the parameters of blur kernel (point spread function angle and length) to perform deconvolution.

2.1.1 Deconvolution using weiner filter

This approach requires prior knowledge about parameters of point spread function. An estimate of a desired random process can produce by weiner filter using linear time-variant filtering of an observed noisy image. Using the deconvwnr() we can deblur a blurred image. Wiener deconvolution 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 Wiener filter reduces to the ideal inverse filter [17]. Weiner filter minimize the mean square error between the estimated random process and the desired process. Weiner filter have been used with fast Hartley transform (FHT) to increase the speed of deblurring process. Result of motion deblurring using this approach shown below [32] using fig. 4, 5, 6.

Fig.4. Original image

Fig.5. Motion blurred image

Fig.6. Motion deblurred image using weiner filter

2.1.2 Deconvolution using regularized filter

It is another category of non-blind deconvolution. It uses regularizing filter for deblurring purpose. This technique is useful where limited information about noise is present. In regularized filtering less prior information is required for deconvolution. Output of motion deblurring using regularized filter is shown below in fig. 7 [17, 34].

Fig.7. Motion deblurring image using regularized filter

2.1.3 Deconvolution using Lucy-Richardson

The LR algorithm can be used efficiently in that case where the point-spread function PSF (blurring operator) is identified, but modest or no information is available for the noise. It is an iterative method to restore blurred image which is blurred by known PSF. One main problem with basic LR method is how many times process should repeat. If no. of iteration very large then it will slows down the computational process as well as amplifies noise and introduce ringing effects. Solution of this problem is modified LR method. In this method first take DWT of blurred image then will be dividing into four sub-frequencies bands (LL, HL, LH and HH) and then apply LR method on Low frequency part (LL). Repeat this process for remaining bands. Motion deblurred image using LR method is shown below in fig. 8 [30].

Fig.8. Motion deblurring image using LR filter

2.2 Blind Deconvolution

Blind deconvolution method as its name indicates it works blindly means it is useful where no information about point spread function or blur operator (PSF) is present. This method using a deconvblind() function for the purpose of deblurring. It will restore the image and the resulting PSF simultaneously. In this method, initial guess about PSF parameters is using for the purpose of deblurring. It is an iterative method means it will use many iteration in the deconvblind() function to derblur the image. Motion deblurred image is shown below in fig. 9. Result of blind deconvolution is better than other previous techniques [6, 9, 12].

Fig.9. Motion deblurred image using blind deconvolution

Blind deconvolution method is mainly of two types: one is projection based and second is maximum-likelihood method. Projection based approach will restore the resultant PSF and the true image concurrently. This technique is cylindrical in nature and repeat continuously until it met a predefined criterion. Firstly we will try to estimate the PSF and then estimate the true image. One of the advantages of this method is that it can easily handle the inaccuracies of support size and it is not sensitive to noise also.

The second approach as its name indicates maximum likelihood estimation of blur parameters like PSF and covariance matrices will find out. Because estimated PSF is not unique then we can take other things in consideration which are size, symmetry etc of the estimated PSF. One of the main advantages of this method is that its computational complexity is low and also helps to find out blur, noise and power spectra of the true image [6].

Apart from these basic techniques there are some other approaches also which are explained here:

2.3 Hyperspectral Image Deblurring (Using Principle Component Analysis)

This technique use PCA to decorrelate the hyperspectral image and separate the information content from the noise. The first k PCA channel contains most information of the HS image and the remaining B-k channels contain information about noise. If deblurring is performed on these noisy and high-dimensional B-k PCs, then it will amplify the noise of the data cube and cause high cost of computation during data processing, which is not desirable. Therefore a fast TV (total variation) method with group sparsity is implemented to jointly denoise in the remaining PCA channel using a soft-thresholding scheme [29].

2.4 Deblurring using Neural Network Approach

A set of multiprocessor computer system contains simple processing elements and a high degree of adaptive interconnection between these elements form a neural network. Using this approach blur PSF is assumed as uniform. Divide the image into various parts and then apply image deconvolution algorithm on different parts. Before applying deconvolution algorithm on blurred image, train the network using back propagation algorithm for number of repetition used in deblurring process to find out the value of true PSF [36].

2.5 Deblurring With Motion Density Function

This method was proposed only for a single blurred image to remove camera shake from it. In this method, motion density function i.e. MDF is represents the motion of camera. As its name indicates, it uses motion density function to records that time fraction which was spent in each discretized part of the space of all the possible camera poses. This method is useful for directly estimating spatially varying point spread function [37]. The main disadvantage of this method is it can't work for multiple images.

2.6 Deblurring With Handling Outliers

According to this method, image pixels are divided into two categories: Inliers and Outliers. Inliers pixels are those which will be covered under limited dynamic range of camera sensor. Outlier's pixels are non-gaussian noise which causes ringing artifacts in the resultant restored image. This type of noise cannot be handled through other existing methods. To overcome this problem a method i.e. Expectation-Maximization method is working to repeatedly improve the outlier classification and the latent image [24].

2.7 Deblurring With ADSD-AR

In this methodology ASDS (adaptive sparse domain selection) plan is presented, which takes in a progression of minimal sub-lexicons and appoints adaptively every neighborhood fix a sub-word reference as the inadequate area. With ASDS, a weighted L1-standard scanty representation model will be the IR assignments suggested. The best fitted AR models to a given patch are adaptively selected to regularize the image local structures [4].

2.8 Deblurring Using Blurred/Noisy Image Pairs

In this approach, the image deblurring process works with the help of noisy image. This process is a two step process. First step used both the images (blurred and noisy) to find an exact blur kernel. To get blur kernel from one image only it is often very difficult. Second step is to perform a residual deconvolution to reduce artifacts that appear as supurious signals which are common in image deconvolution. Now, in the third step the remaining artifacts which are present in the non-sharp images are suppressed by gain controlled deconvolution process. Advantage of this method is that it will use both images and produce a high quality reconstructed image as a result [18].

Table 1: Performance analysis of deblurring methods

Methods name	Types of blur	Performance	PSNR ratio
Weiner filter	Gaussian blur	bad performance	17.05
Lucy-Richardson	Gaussian blur	Efficient	21.06
Regularized filter	Gausian blur	Efficient	20.10
Blind deconvolution	Gaussian and Motion	Efficient	26.78
Hyperspectral (PCA)	Hyperspectral image blur	Efficient	22.34
Neural network	Gaussian and out-of-focus	Very efficient	30.11
Motion density	Motion	Efficient	24.31

function			
Handling outliers	Gaussian	Efficient	21.90
ADSD-AR	Gaussian	Very efficient	31.20
Blurred/Noisy image pair	Gaussian	Efficient	23.37

3. CONCLUSION

A number of methods have been developed by various researchers for image deblurring or image restoration. Till now, image deblurring is a challenging issue. By analyzing various methods, we conclude that in the category of Non-blind methods, wiener filter give worst performance, its PSNR (peak signal to noise ratio) value is low as compared to other techniques and LR method is good, its PSNR value is high as compared to other methods. Blind deconvolution method is gives best result in comparison with non-blind techniques. Blind deconvolution method can also be used for non-uniform motion deblurring using segmentation and motion blur estimation method. It is a two step procedure. In the first step, segment the image into foreground and background. Second step is to estimate motion blur parameters and then use those parameters for deblurring. From other techniques, ADSD-AR gives highest PSNR value. Future scope is to design a hybrid technique to get better result.

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