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A Review on Image De-blurring Techniques

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Abstract-

Image blurring in digital image is one of the severe artifacts which need to be corrected for keeping the quality of the image good. Blurring in the image make the image looks hazy and unclear. Image enhancement or image de-blurring is techniques which deal with this problem. Image de-blurring is the image processing operation which is used reduces the quantity of the blurring in the image. This paper present a review work on the image de-blurring techniques so far proposed or presented in various journals.

Keywords- PSF(point spread function)**,** blur kernel, De-convolution , Image De-blurring

I. INTRODUCTION

Quality of the image play important role in recognizing and interpreting the vital information present in the image. Haziness and distinctness are the main hurdles in clear sound and visuals and image taken during this phenomenon have very severe impact on the image. This in turn deteriorates the quality of the image. This deterioration of the quality of the image due to the above mentioned reason is known as the blur [1].

In real world each and every image are more or less blurry. The main cause of the blurring of the image is environment and limitation in camera. Though there are more reason for blurring image one such example is taking a snap during the motion. Long exposure time, application of wide angle lens is some of the other reason for image blurring. Image de-blurring the well known image processing technique which is used to sharpen the image by using some mathematical model.

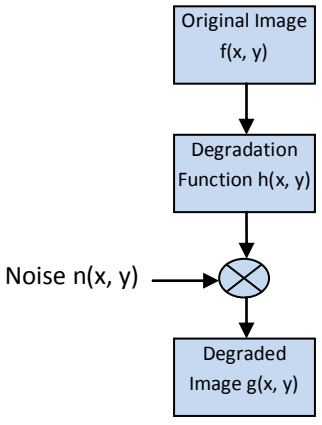

Figure 1 Image Degradation Model

Digital image restoration technique can be thought of as the process try to find out the closest approximation to the f(x,y).

The basic method which is adopted for image deblurring is to get the information which causes the blur. Once the real reason of the cause of the blur is acquired then proper algorithm is applied to revert back the effect of the blur and reconstruct the image. So in any image deblurring techniques effective knowledge of the cause of the blur is utmost important.

Once one estimates the parameters which cause the degradation then proper restoration techniques ensure the true reconstruction of the image.

1.1 Image degradation Model

Following model describe the model of image degradation.

Input to this model is a two dimensional image f(x,y). h(x, y) represent the degradation function. N(x, y) represent the noise adding in the image during the acquisition period or transmission period. The output of the model is represented by the g(x, y) which is a degraded image[2].

Figure 2 Image De-blurring illustration

Figure 3 Blurred Image(Left) and De-blurred Image(Right)

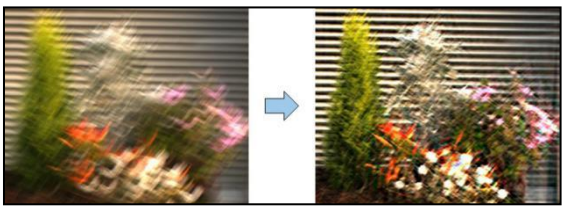

Figure 4 Blurred Image(Left) and De-blurred Image(Right)

Mathematically image de-blurring can be represented as

$$G(x, y)=h(x, y)*f(x, y)+n(x, y)$$

1.2 Blur Type

Basically there are four common types of blur effect in digital camera.

1.2.1 Average Blur:

Average blur is basically an image processing tool to get rid of noise and other artifacts from the image. It is used in the image if noise is present all over the image. This type of blurring is applied horizontally and vertically and by circular averaging by radius R which is computed using following formula[3]

Here g is the blurring size along horizontal direction and f is the blurring size along vertical direction. R represents the radius size of circular average blurring.

1.2.2 Motion Blur

Motion blur is basically caused by the relative motion between the image capturing device and scene. This type of motion blur can be in the form of rotation, translation, variation in scale or some combination of these. A motion blur effect can be introduced in the image by applying appropriate filter in particular direction.

1.2.3 Gaussian Blur

Blurring effect produce in the image after applying the Gaussian function is known as the Gaussian blur. It is mostly widely used effect in the graphics software for removing the Gaussian noise from the image or for removing the fine details from the image. In so many applications, Gaussian blur is used in a pre-processing stage for enhancing the image. Gaussian function is a bell shaped curve. Due to the bell shaped curve, blurring is more dense in the centre as compared to the edge[4].

1.2.4 Out of Focus Blur

This type of blur is produced when one take the picture of a 3-D scene in to a 2-D imaging plane. In this case, some parts of the scene are in focus while the other parts are out of focus. If the aperture camera aperture is circular then the image of the point source is found to be small disk which is known as the circle of confusion (COC). The degree of defocus depends on the focal length and aperture number of the lens. It also depends on the distance between camera and the object.

II. RELATED WORK

In the year 1992 Bennia A et.al in his paper[5] titled "Filtering Capabilities and Convergence of the Van-CittertDeconvolution Technique", presented another iterative based image deblurring technique. In this technique, first of all a difference between estimated image and the original image is computed and then iteration is performed till the difference reaches its minimum. Mathematical formula for this is shown in the equation

$$f_{n+1} = f_n + (g - hf_n)$$

Where f n+1is the new approximated value of the function while

fn is the previous value of the function , g is the captured blurred image, n is the number of the iterations, H is PSF and in the first iteration, fn is same as blurred image g. One of advantage of this algorithm is that it contains simple mathematical operations. The limitations of it are sensitive to the noise in an image, unstable after some limit of iterations and the image can be look like shaky.

In the year 1996 Kundur, D. and Hatzinakos, D. In their article[6] " Blind image deconvolution revisited" describe the procedure of blind deconvolution method. In this article they describe that there are basically two types of blind deconvolution method first is projection based blind deconvolution method and second is maximum likelihood restoration based blind deconvolution method. In the first approach, restoration of true image and point spread function is carried out simultaneously. This method first estimates the true image and PSF initially. First of all PSF estimation is carried out followed by the estimation of the image. This process is repeated till the predefined convergence is satisfied. One of the advantages of this approach is that it is less sensitive to noise. The disadvantage of this method that it is not unique and show some error associated with the local minimum.

In the second method, maximum likelihood estimate of the PSF and covariance matrix is carried out. Since PSF estimate is not unique some other assumption like symmetry, size etc of the PSF is also considered. Low computational complexity and obtaining the blur, noise and power spectra of the true image are some of the advantages of this method. Converging to the local minima is the disadvantage which is associated with this algorithm

In the year 2003L.Lang and Y.Xu in their paper[7] titled ", "Adaptive Landweber method to deblur images" suggested a enhanced version of Van Cittert method. Their proposed method is also iterative. This method gives more reliable and accurate result for increase number of iterations. This method adopted a following equation

$fn+1 = fn + \beta H (g-H)$

Here f n+1is new value of the function and fn is old value. G represent the blurred image, n represent the number of iteration, Blur function also called PSF is represented by H, β *is* sharpening constant which decides the sharpening level. Higher computational time is the disadvantage of this algorithm.

In the year 2006, Levin A. In his paper [8] titled " Blind Motion Deblurring using image statistics" applied image statistics to deblur the image accurately. In most of the cases single blur kernel is used for deblurring operation but when blurring is caused in the image due to the motion in different direction then single kernel fail to produce good result. It is because of this different kernel are required for deblurring.

It is observed during the deblurring operation, statistics of the derivative are different for different blur kernel.

This algorithm searches for mixture model which define the image distribution. This operation give two blur kernel. The output of this method is a rich texture image. This algorithm also has some limitation like using box filter, unknown direction of the blur, fail to describe the blur size.

In the year 2006, Hu.H.andHaan G. In their paper[9] " Low cost robust blur estimator" suggested a deconvolution method which is based on the estimation of the blur kernel. In this approach the input image which is already blurred is first re-blurred with the help of Gaussian blur kernel of different blur radius. Ration of different reblurred images are then used for determining the unknown blur radius. These radius are independent of the edge positions and amplitude. This method does not need computation of edge direction and detection.

In the year 2007, Yuan L. Et.al.in their paper[10] titled " De-blurring with blurred/noisy image pairs" presented novel approach of de-blurring the image

In this method image de-blurring is performed with the help of blurred or noisy image. In this method , first of all both the two images are blurred and then with the help of noisy image, accurate blur kernel is obtained. For obtaining the blur kernel more than one images are used as the blur kernel obtained by the single image is not very accurate. After this step, Residual de-convolution is performed to get rid of artifacts appear in the image due to various image operation.

In the year 2011,Nishiyama, M.et. al. Published a paper[11] under a title "Facial de-blur inference using subspace analysis for recognition of blurred faces". In this paper they used subspace analysis to de-blur the image. In this approach, first of all authors prepared a training set which consist of blurred image. These images are used to extract some of the vital information. Then a feature space is prepared in such a way that the blurred faces with same point spread function are similar.

In the year 2012, Zohar-al-ameen et.al in his paper[12] titled " A Comprehensive Study on Fast image Deblurring Techniques", describe iterative poisson Map algorithm which is also an iterative algorithm. This algorithm is same as Richardson-Lucy algorithm with only difference is that this algorithm uses formula in the form of exponential. This method follows the following equation

$$fn{+}1 = fn\,[HgHfn - 1]$$

Here, *f* n+1 represent the new approximation value,

*f*n is previous value , g represent the blurred image, n is number of iteration, H is PSF. Since in this algorithm exponential formula is used which puts some limitation in this algorithm. Computational it is complex due to the use of exponential function and hence require more time .

In the year 2012, Zohar-al-ameen et.al in his paper[12] titled " A Comprehensive Study on Fast image Deblurring Techniques", describe Laplacian Sharpening filter based image de-noising. Laplacian sharpening filter is basically used for sharpening the image. Image sharpening operation can be considered as the image de-blurring operation. Laplacian filter is basically 3x3 window matrix which is of three different types depending upon the weight given to the centre pixel. These filters are shown in the figure given below. It is very fast algorithm and not a iterative type method.

0	1	0
1	-4	1
0	1	0

1	1	1
1	-8	1
1	1	1

-1	-1	-1
-1	9	-1
-1	-1	-1

Figure 2 Laplacian mask

In the year 2012 Jiunn-Lin Wu et.al in his paper[13] titled " An Improved Richardson-Lucy Algorithm for Single Image De-blurring Using Local Ext-rema Filtering" suggested a modification in the old Richardson-lucy algorithm of de-blurring. One of the advantage of this algorithm is that it is noise invariant and it is also an iterative algorithm.

The equation for this algorithm is given below

$$f_{n+1} = f_n H(\frac{g}{hf_n})$$

Here *f* n+1is the new approximated value of the function and

*f*n is the previous value of the function, g represent the blurred image n represent the number of iteration. H represent the Point spread function(PSF). For the first iteration fn is same as g. This method minimizes the difference between predicted and blurred image with the help of poisson statistics.Ringing effect and more computational time for more iteration are the two drawbacks of this approach.

In the year 2012 Sitara K and Remya S published a paper[14] titled "Image De-blurring In Bayesian Framework Using Template Based Blur Estimation" In this method degraded image has been used for reconstructing the high quality image. In order to perform de-blurring operation, a blurring function which is responsible for the degradation is computed first. This method is template based method which are able to identify Gaussian based blur and uniform blur. For incorporating prior knowledge in data analysis, Bayesian approach has been taken in this project. Foe performance measure, PSNR(Peak Signal to Noise ratio), SNR(Signal to Noise ratio), SSIM(Structure Similarity Index) and IQI(Image Quality Index) are used. Experiments were carried out by taking different blur parameters.

For uniform as well as the Gaussian blur. Both color and gray scale images have been used for testing the performance of the method. Limitation of this approach is that it can only recognize and deblur the Gaussian and uniform blurred images.

In the year 2013 M. F. Fahmy et.al.in their paper[15] titled "A New total variation based Image De-noising and De-blurring Technique"

(IEEE) proposed a total variation based image de-noising algorithm.

This method attempt to find the threshold level of the noisy image wavelet decomposition which minimize the energy error between noisy and restored image. The selection of optimal threshold level is achieved in this algorithm. First and second order derivative of the noisy image is used for regularizing the minimizing the algorithm. Experimental results show the significant level of improvement in de-noising and de-blurring the noisy image.

The performance evaluation is carried out by restoring the blurred noisy images. First of all the image is blurred using Gaussian filter of size 8x8. Later on the image is then contaminated either by applying zero-mean Gaussian noise with variance 0.005 or by applying the salt and pepper noise with density 0.005. once the image is contaminated with the noise then the proposed total variation based method is applied to de-noise and de-blurred the image.

In the year 2014 Kit Yan Chan, et.al.in his paper[16] titled "Image De-blurring using Hybrid Optimization Algorithm" presented an image de-blurring method which was based on the hybrid optimization. In this method they have combine the particle swarm optimization (PSO) and gradient search method for optimizing the PSF parameter. Main aim of this hybrid method is to utilize the advantage of these method. PSO is very good at localizing the global region while gradient search method is good at converging these locals in to a local optimum. Simulation results shows that this method successfully achieved the de-blurring of the image by computing the optimal PSF using hybrid optimization method. One of the limitations of this method is that it tends to produce the ringing artifacts in the image apart from de-blurring the image.

As for as evaluation scores is concerned, this method proved to be improved by more than 10% relative to blind convolution method, Lucy richardson method and Wiener method. It has also shown improvement over the other de-blurring method such as Genetic algorithm based de-blurring, PSO based image de-blurring in which

PSF are optimized using these optimization method. This method also showed 3.5% better result than the regularized filter based method.

Table 1 Comparison of Major Algorithm

PSF	Algorithm	Computational Operation	Execution Time	PSNR
Gaussian (3x3 window)	Blur	-	-	34.67
	Iterative Richardson Lucy	4	0.142	41.33
	Iterative Van Cittert	4	0.087	42.54
	Iterative Landweber	5	0.120	42.30
	Iterative Poisson Map	6	0.117	41.82
Laplacian Radius (1)	Blur	-	-	28.63
	Iterative Richardson Lucy	4	0.1206	30.18
	Iterative Van Cittert	4	0.0940	30.06
	Iterative Landweber	5	0.1320	30.03
	Iterative Poisson Map	6	0.1219	27.85

In the year 2014, Michael H. Ferris et.al. presented a paper[17] titled "Extension of No-Reference Deblurring Methods through Image Fusion"(IEEE) In this method , first of all optimal information from the blurred image is obtained without taking a reference image. Image fusion is used in this method for obtaining the optimal information about the blurring in the image. In this method first a de-blurring is applied to a no reference image and then fused it with the blurred image. One of the limitation of this algorithm is that it loses some amount of information. For evaluation the proposed method some metrics such as Mutual Information (MI), Mean Square Error(MSE) and Peak signal to noise ratio(PSNR) is used.

Experimental results show that the proposed method is able to increase the MI and PSNR while able to reduce the MSE. The results revealed the facts that this method has increasing relationship with the blurriness of the image.

In the year 2014, Tao Yue et.al. in their paper[18] titled "Hybrid Image De-blurring by Fusing Edge and Power Spectrum Information" Suggested a hybrid De-blurring approach is based on the edge-based and power spectrum based approach.

This method first of all, extract the edges from the images. This edge information is then used for estimating accurate power spectrum of the kernel. Edge and power spectrum information are then combined for estimating the kernel accurately by optimization techniques. experimental results obtained by this method shows better performance than either edge based approach or power spectrum based approach. One of the drawback of this method that is not able to handle the significant non-uniform blur. It is due to the fact that power spectrum estimation is computed on global level and does not count spatially-varying blur.

III. CONCLUSION

In this paper an attempt has been made to analyse and discuss some of the common techniques of image de-blurring. On the basis of this study and simulation result conclusion has been drawn. A comparison table has been prepared for better understanding of all the common image de-blurring techniques and shown in table 1. As per the data, tabulated in table -1, as far as computational operation is concerned, Richardson lucy, Gaussian and Cittert techniques are efficient as they require less mathematical operation for de-blurring. Iterative poisson map require most number of mathematical operation and hence proved to be inefficient in term of mathematical manipulation.

As far as the quality of the result is concerned, laplacian perform poorly due to the fact that its PSF is not set according to the blur in the image.IterativeVan Cittert registered a Highest PSNR value which confirms its usefulness in term of quality of the image. In term of execution time Iterative Van Cittert registered a least execution time due to the least number of computational operation.

As far as performance in noisy image in concerned it can be concluded that all the algorithm discussed in this paper fail to perform good result.

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