Review of Techniques and Methods for Image Deblurring

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Abstract— Technological advancements in the scientific world has witnessed its exponential growth since the transformation from analogue to digital devices. Computer Systems transitioned from humongous sized poor performance gadgets to powerful computational devices even surpassing the human intelligence in most scenarios. Such advancements gave birth to algorithmic approach to world most complex problems. As algorithms, for their decision making requires data, which in most cases is in the form of images, those images for the sake for better processing needs to be clear with sharp edges, which simply means there shouldn't be any kind of blur or noise effecting those input images. Blur or noise are added to the input images during the capturing process either because of the natural scene lighting or the complexity of scene or because of convolution of impulse response which is called as blur kernel or point spread function(PSF). Image processing field which deals with deblurring of such images is called as image restoration. There are two methodologies for dealing with such scenarios that are blind image deblurring and reference based image deblurring. This paper gives extensive review of research done in both domains. Discussing in details the approaches been used along with comparing the data to analyze and specify the methodology that is well suited for most blur scenarios.

Keywords— Image Processing, image restoration, blind image deblurring, conventional image deblurring.

1. INTRODUCTION

Over the years our dependence on the algorithms has increased significantly in every domain of our life ranging from medical diagnosis to satellite imagery, security to industrial processes.

In each of these domains one factor that is common is the need of images either in shape of single image or videos, which are fed to the systems to get the desired output.

But for the images to be well interpreted they must be clear which in the field of image processing means there should not be any sort of degradation in the image either in the form of blur or noise.

Because additions of such degradations will affect the readability of those images which in return will affect the output of algorithmic process. To avoid such degradations in the input images another field in the image processing has emerged which is known as image restoration.

In the field of image restoration, reversal of an image from its degraded version to a clear, natural scene replica version is a well-established issue. Because there isn't any single generic equation through which any blur image can be deblurred.

The reason for its absence is the nature of degradation which can be in quite a number of forms. In case of blur affected images that blur kernel can one or combination of many blur kernels, can be space variant or space invariant, can be parametric or non-parametric.

So deducing single equation for all these possibilities is a challenge that is yet to be completed. Like blur, noise is also a degradation factor which can also be added due to many reasons, like poor camera lens calibration, scene lightening etc.

For tackling image degradation, different deblurring techniques are introduced over the years. These techniques are generically divided into two categories depending upon the information we have related to the blur image.

One is reference based image deblurring where either we have information related to the Point Spread function (PSF), which is impulse response convolved with the original image at the time of capturing process or we have true image which can be utilized by the optimization algorithms as the stopping criteria when required MSE between the deburred image and original image is achieved or by the machine learning algorithms for training.

The second category is reference-less or blind image deblurring where neither we have any information related to the blur kernel nor we have the true image.

This paper will give extensive review of the research done in the field of image restoration.

Review section will be divided in above-mentioned two generic image restoration categories. It will also discuss the data from different research approaches and will analyze which restoration algorithm yields better results.

1.1 PROBLEM STATEMENT

Addition of blur or noise that is added to the images is an undesirable phenomena especially in scenarios where such degradations is highly unacceptable like that of medical imagery where critical decisions depends on such images or in satellite imagery where sending probe or satellite back to last known locations for a single image is financially not feasible or in CCTV footage which is really important for security. For tackling such scenarios, algorithms must be developed, which can efficiently remove the unwanted blur and noise from the image. But unfortunately these degradations cannot be presented with a single mathematical equation which results in the complexity of resolving such issues. Various types of blur are discussed below:

Camera Shake Blur:

With handheld photography devices in trending, inclusion of this kind of blur in images has increased significantly because this blur is added to an image when the camera is moved (translated or rotated or both) during capturing process. Movement is not the only reason, low lightening condition of the scene can also cause the addition of camera shake blur. Below figure depicts camera shake blur.

Figure 1: Camera Shake Blur [1]

Atmospheric Turbulences:

In scenarios like satellite imagery, or other long range image capturing systems, often temperature variation or wind which causes light rays refractions causes atmospheric turbulence blur. Figure 2 depicts atmospheric turbulence effected simulated image.

Figure 2: Atmospheric Turbulence [1]

Motion blur:

At the image capturing instance both the camera device and the object must be stationary, if either moves, it will cause the addition of motion blur in the image. Along with the movement, low exposure time is also the cause of this kind of blur. Figure 3 show the simulated motion blur effect.

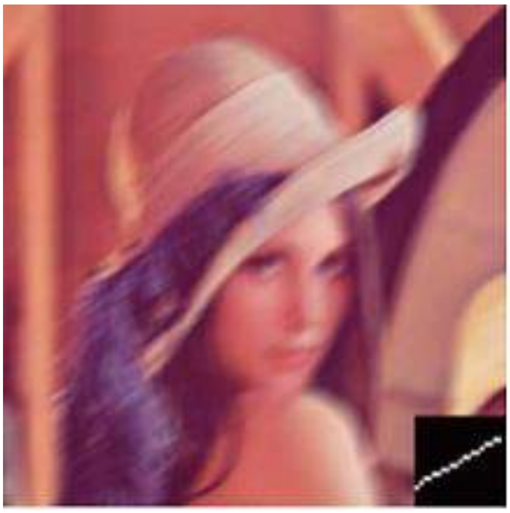


Figure 3: Motion Blur [1]

Imperfect Focus:

External factors like temperature, wind, motion, camera shake are not the only factors for the inclusion of blur in an image, but sometimes poor calibrations of camera lenses can also cause degradation in an image. This kind of blur is known as imperfect focus blur.

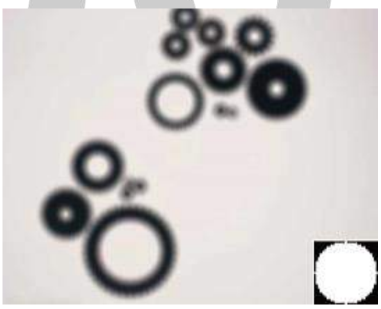


Figure 4: Imperfect Focus [1]

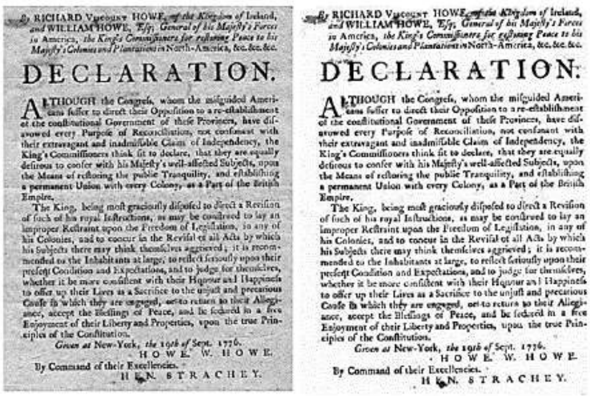
2. TECHNIQUES AND METHODS

As deblurring methodologies are grouped into two major categories that are reference based image deblurring and reference-less image deblurring. Hence this section is divided such that research work done in each category is explained separately.

2.1 Reference Less/Blind Image Deblurring

Finding blur kernel for the blurred image is always a challenge in image restoration. Different techniques are used for its retrieval, one technique among many, is the use of optimization algorithms that are Genetic algorithm, Ant colony algorithm and Particle swarm optimization. These optimization algorithms converge toward local and global minima in the most efficient way which helps tremendously in finding the blur kernel parameters

In [2] they have presented a technique where Genetic algorithm optimization is utilized for deblurring of old documents, documents that are hundreds of years old. Digitizing such documents manually will take ages and will be prone to errors. Speeding up this process requires automatic system like OCR or document scanning etc. But such methodologies are also liable to the addition of blur or noise. The solution for such an issue is presented by this research work where they have enhanced fitness function calculation presented by [3], where number of edges are summed up for fitness function which in case of old documents will fail because old documents were hand written where edges length might vary, so for avoiding just ambiguities. They have enhanced this system by calculating only those edges that are defined by single pixel. Along with defining the fitness function they also have experimented on median of the image which shows that images preprocessed with median filter does not yield better results. Figure 5 depicts the output of above proposed methodology.


By RICHARD Viscount HOWE, of the Kingdom of Ireland, and WILLIAM HOWE, Esq; General of his Majesty's Forces in America, the King's Commissioners for restoring Peace to his Majesty's Colonies and Plantations in North-America, &c. &c. &c.

DECLARATION.

ALTHOUGH the Congress, whom the misguided Americans suffer to direct their Opposition to a re-establishment of the constitutional Government of these Provinces, have disavowed every Purpose of Reconciliation, not consonant with their extravagant and inadmissible Claim of Independency, the King's Commissioners think fit to declare, that they are equally desirous to confer with his Majesty's well-affected Subjects, upon the Means of restoring the public Tranquility, and establishing a permanent Union with every Colony, as a Part of the British Empire.

The King, being most graciously disposed to direct a Revision of such of his royal Instructions, as may be construed to lay an improper Restraint upon the Freedom of Legislation, in any of his Colonies, and to concur in the Revisal of all Acts by which his Subjects there may think themselves aggrieved; it is recommended to the Inhabitants at large, to reflect seriously upon their present Condition and Expectations, and to judge for themselves, whether it be more consistent with their Honour and Happiness to offer up their Lives as a Sacrifice to the unjust and precarious Cause in which they are engaged, or to return to their Allegiance, accept the Blessings of Peace, and be secured in a free Enjoyment of their Liberty and Properties, upon the true Principles of the Constitution.

Given at New-York, the 19th of Sept. 1776.

HOWE. W. HOWE.

By Command of their Excellencies.

HEN. STRACHEY.

(a) (b)

Figure 5: (a) Blur Image and (b) Proposed methodology [2]

With the increasing popularity of smart phones, handheld photography has been in the spotlight. But with the reliability in the capturing of real-life moments, absence of high-end hardware, causes the images to be prone to blur, especially camera shake blur and motion blur. The reason for camera shake blur as mentioned in this paper, might be the complex structure of the real-life environment or the long exposure time of the capturing process. Quite extensive research is being going on in this domain of image restoration. The solution proposed by [4] is to utilized the single blurring image for the deblurring of whole video sequence while assuming the availability of depth map of the observed scene and fixing the scenario that the small camera motion affected the image. There focus is on the calculation of not only the non-uniform blur kernel but also on the estimation of 6 Dof camera motion, because by doing so, not only plane images but videos with depth factor can be deblurred with ease while keeping the video frames sequence in order to keep the video quality sharper. For initial experimentation datasets like that of KITTI and Middlebury were used where synthetic blur were introduced on real life images but both of these datasets lack the presence of depth map, for which another dataset, TUM RGB-D was utilized. Figure 6 shows the outputted results.

(a) (b)

Figure 6: (a) Blur Image and (b) Proposed methodology [4]

In [5] for the construction of arbitrarily shaped PSF three optimization algorithms were utilized for PSF quick convergence, among the three algorithms there experimented results depicted that the convergence rate of Particle swarm optimization is much faster than that of the other two that are Ant Colony Optimization and Genetic algorithm. However in terms of programmatic implementation Genetic algorithm leads the way as compared to the other two algorithms. Outputs are presented in figure below.

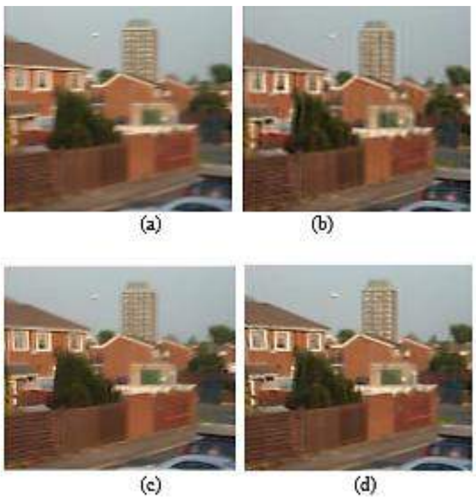


Figure 7: (a) Blur Image (b) Genetic Algorithm Deblurring (c) Ant Colony Deblurring (d) Particle Swarm Optimization Deblurring [5]

In [6] they have utilized the Genetic algorithm for the local minima convergence for the PSF values which were used by the deconvolution algorithm to generate deblurred images, which after deconvolution were analyzed for the whitenss of the residual image. The outputted value determined the iteration status, either to stop the process or to keep going. Same Genetic algorithm is also utilized in [7] where PSF values specifically for the Gaussian Blur parameters were generated. The generated population of Gaussian blur sigma values were utilized by the Weiner filter for deconvolution. The resultant images were passed through Kurtosis function for analysis, which determined whether the image is deblurred or not. Depending on the output of the Kurtosis function the iteration status was determined. Results of above methodology is presented in Figure 8.

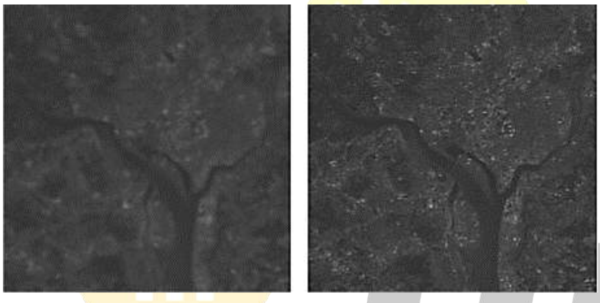


Figure 8: Gaussian blur effected image with sigma=2 and resultant output image with proposed scheme with calculated sigma=2.33 [7]

With the advancement in the mobile phone systems, applications like gyroscope and accelerometer are widely used in almost all the mobile devices. In [8] they have proposed a techniques depending on above mentioned features of today's smart phones. At every instant of using mobile devices, data related to gyroscope and accelerometer is saved. Upon accessing that data at the time of capturing of blurred image, it can be utilized by Particle swarm optimization to generate PSF values from it. Motion vector can be calculated by the motion of cellphone during image capturing. Below figure 9 outputted results depicts the efficiency of the above proposed scheme.

Figure 9: 1: True Image 2: Blind Deconvolution 3: Wiener filter 4: Deblurred by Lucy-Richardson method, 5: Regularized filter Method, and 6: proposed methodology [8]

In [9] methodology for bulk image deblurring is presented where a unique approach of utilizing the basis and corresponding coefficients of blurred images are utilized. This process works amazingly for many blurred images like in the case of video processing. Where different frames are to be deblurred. Values calculated for one image is utilized for the whole sequence. Thus minimizing the computational workload significantly. Figure 10 shows the results of proposed approach.

(a) (b)

Figure 10: (a) Blurred image and (b) Deblurred Imaged [9]

Often images restored by the deblurring process losses its detail. Which in cases like pattern recognition of tissues patterns or satellite imagery, is unacceptable. To address this problem, an effective approach is presented in [10]. There proposed method involve the use of most popular neural algorithm, BP neural network, which upon the utilization of fractional form error functions as its core error function and particle swarm optimization for its optimization, yields better results than traditional deblurring techniques like that of Wiener filter deconvolution, constrained least square (CLS) deblurring method and many more. Upon experimentation they have proposed that deblurring with CLS smoothed the sharp edges hence affecting the important details while on the other had Weiner deconvolution is better in removing blur but it creates more jagged edges. 6 real life images were tested with all the above-mentioned algorithms after training the BP neural network. The results obtained from proposed methodology retains the fine details in the deblurred image along with the removal of blur from the image.

2.2 Reference Based Image Deblurring

In most of research work presented, spectrum of the blurred picture is utilized for finding the angle parameter of the blur kernel while Hough transform is utilized for the direction in which blur kernel was convoluted with the original image. But a different technique is introduced in [11] which is based on equation given in [12], where instead of above mentioned methodology they have proposed a new scheme which utilized the frequency domain representation of blurred image, and they have utilized cestrum instead of spectrum for finding the angle while for direction they have utilized Radon transform. But this algorithm fails in case of real life blur kernel as those blurs are of irregular shapes.

Table 1: Proposed methodology on various images [11]

Image Name	Actual Theta	Estimated Theta	Actual Length	Estimated Length
Car1	30	34	60	62
Car2	30	33	50	50
Bike	45	48	65	66
Gate	30	32	45	45
Ground	10	11	55	55
Face	9	10	31	30
Peacock	2	3	50	49

Figure 11: Deblurring with values from table 1 [11]

As in reference based image deblurring we either have knowledge related to PSF or true image. In [13] restoration of blurred images is performed by utilizing Richardson-Lucy deconvolution algorithm instead of wiener filter while having prior information related to PSF along with focusing of Poisson noise instead of Gaussian noise. For deconvolution different algorithms are used, some of those popular algorithms are, Algebraic deconvolution, Basis Pursuit deconvolution and Richardson Lucy algorithm [14].

In [15] above mentioned three deconvolution algorithms are compared with experimentations. There outputted results depict that Basis Pursuit deconvolution yields sharpest results of all and along with that it's really amazing when it comes to suppressing the ringing effect. But when it comes to execution time Algebraic deconvolution performs the best while its ringing suppression quality was the worst.

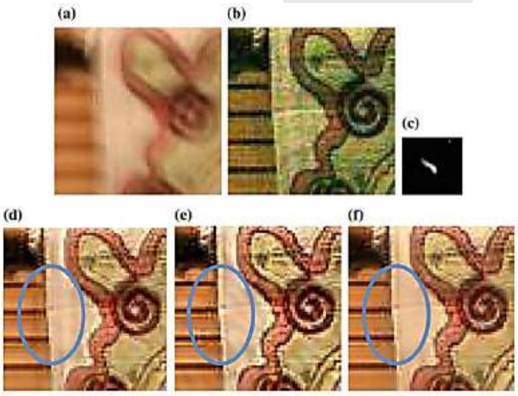


Figure 12: (a) Blurred Image (b) Noisy Image (c) Blur kernel (d) Richardson Lucy result (e)Algebraic deconvolution result (f) BPD result [15]

Identifying the optimal solution or local minima for a problem having different solution possibilities is computationally expensive because to accept a specific optimal solution the algorithm has to traverse through all the possible solutions first, such problems lies in the category of nonconvex optimization problem.

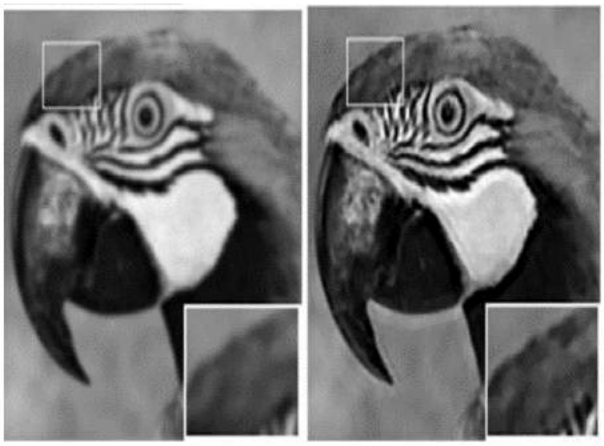
In [16] they focus on the objective of obtaining a blur free image along with the calculation and identification of the blur kernel which pushes it to the category of nonconvex optimization.

They have constructed an algorithm based on proximal alternating minimization (PAM). But for the algorithm to generate better results an initial point must be given to it that's the reason their algorithm is semi-blind deblurring algorithm.

Proposed algorithm works better then TV-RSTLS, no matter the blur kernel, given the initial guess for both the algorithms is same.

Blur kernels under considerations were Moffat kernel, Gauss kernel and truncated non-symmetric kernel.

Quantitative results were based on the SNR, structural similarity index and PSNR of the resultant images from the both, the proposed methodology and the TV-RSTLS algorithm.



(a) (b)

Figure 13: (a) Blur Image and (b) Proposed methodology [16]

In [17] an approach based on calculation of PSF by finding threshold value is utilized where image is first compressed to 255x255, then PSF values of extreme high and low is applied on it. They have applied Gaussian blur kernel.

The process is repeated till they find the threshold value.

For reducing the ringing effect, they have utilized WEIGHT array method.

In [18] Genetic algorithm is utilized for the generation of random population of PSF values.

From that population PSF values that yields better result is utilized for the generation of another population.

This process continues until we get PSF values that yields the best results.

3. CONCLUSION

Image deblurring has always presented a challenge for the research community no matter if domain in spotlight is reference based image deblurring or reference-less image deblurring. But among the two, reference based image deblurring is relatively easy, computationally less expensive, yields better results than that of blind image deblurring. The reason for such a difference is either because of the availability of true image or because of the availability related to point spread function.

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