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Image Restoration Techniques in Image Processing: An Illustrative Review

Himanshu Joshi [1], Dr. Jitendra Sheetlani [2]

[1] *Research Scholar, Sri Satya Sai University of Technology & Medical Science, SEHORE (MP)*

[2] *Assistant Professor, Sri Satya Sai University of Technology & Medical Science,SEHORE (MP)*

ABSTRACT

In image processing when we apply an image acquisition process on image, the performance of image degraded due to various reasons such as noise, camera mis-focus, random atmospheric turbulence. Image restoration is one of the techniques which can improve the quality of degraded or blurred image but the process to recover image is complex and costlier. There are various techniques of image restoration such as constrained least square filter, blind deconvolution method, Weiner filter, inverse filter etc. This paper presents the literature study about the work done in the field of image restoration and also discusses some techniques of image restoration with their merits and demerits.

Keywords:Image restoration, Noise, Convolution, Weiner filter, Inverse filter.

I.INTRODUCTION

In various field of planetary science to atomic spectroscopy and restorative imaging to satellite imaging. The inconvenience in recouping original image from obscured and noisy image is requesting. Digital image restoration is being utilized as a part of different applications. Just to give some examples, restoration has been utilized as a part of the field of Astronomical imaging, Medical imaging, Restoration of maturing and crumbled films (motion picture restoration), Defense and examination and printing application.[1] Early endeavors to reestablish pictures selected one dimensional signal processing algorithm to image. A few strategies are suggested that are utilized as a part of different applications as needs be. Since their proposition, image restoration has been actualized in different orders including seismology and attractive reaction imaging. Image restoration depends on the endeavor to enhance the nature of a picture through information of the physical procedure which prompted its arrangement. The reason for picture reclamation is to "compensate for" or "undo" defends which corrupt a image. Degradation comes in many structures, for example, motion blur, clamor, and camera mis-focus.[2] In cases like motion blur, it is conceivable to concoct a decent gauge of the genuine obscuring capacity and "fix" the obscure to reestablish the first picture. In situations where the picture is debased by clamor, the best we may plan to do is to make up for the corruption it caused. Picture reclamation contrasts from picture improvement in that the last is concerned more with complement or extraction of picture includes as opposed to rebuilding of debasement. Image restoration issues can be evaluated definitely, though improvement criteria are hard to speak to scientifically. In this paper we presents a review of literature work done in the field of image restoration by various researchers and also discussing the restoration techniques with their merits and demerits. Here fig. 1shows the process to restore the image.

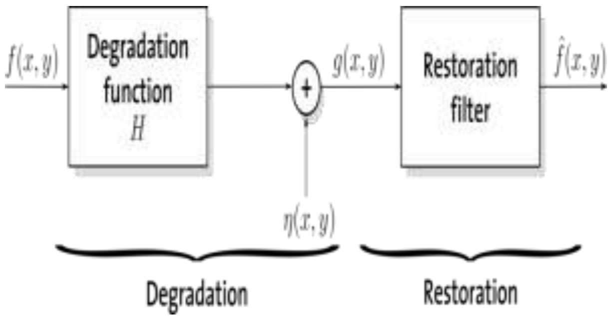

Fig. 1 : Process of Image Restoration

II.TYPES OF NOISE

During image acquisition or transmission, several factors are responsible for introducing noise in the image. Depending on the types of disturbance, the noise can affect the image to different extent. Our main concern is to remove certain kind of noise. So we have to first identify certain type of noise and apply different algorithms to remove the noise. The common types of are:

2.1 Impulse noise (Salt-and-Pepper noise)

This type of noise appears as black and white dots on the entire image. This type of noise is also called by the terms spike noise, random noise or independent noise, data drop noise. This noise is also referred as salt and pepper noise but the image is not wholly corrupted by salt and pepper noise instead some of the pixel values are altered in the image. Although in noisy image, there is a possibility that some of the neighbours does not change.[7]

$$f(z) = \begin{cases} p_a & if\ z = a \\ p_b & if\ z = b \\ 0 & otherwise \end{cases}$$

Where intensity of "b" is white dot (means salt), and intensity of "a" is black dots (means pepper).

Fig.2: Impulse noise

2.2 Poisson Noise

Poisson or shot photon noise is the noise that is caused when number of photons sensed by the senor is not sufficient to provide detectable statistical information. Shot noise exists because a phenomenon such as light and electric current consists of the movement of discrete packets. Shot noise may be dominated when the finite number of particles that carry energy is sufficiently small so that uncertainties due to the Poisson distribution, which describe the occurrence of independent random events, are of significance. Magnitude of this noise increases with the average magnitude of the current or intensity of the light.[7]

$$P\left(f(pi) = k\right) = \frac{\lambda^{k} l^{e^{-\lambda}}}{k}$$

Fig. 2: Poisson Noise

2.3 Gaussian Noise

Gaussian noise is evenly distributed over signal. This means that each pixel in the noisy image is the sum of the true pixel value and a random Gaussian distributed noise value. The noise is independent of intensity of pixel value at each point. A special case is white Gaussian noise, in which the values at any pair of times are identically distributed and statistically independent. White noise draws its name from white light. Principal sources of Gaussian noise in digital images arise during acquisition, for example sensor noise caused by poor illumination or high temperature or transmission.

Gaussian noise:

$$p(z) = \frac{1}{\sqrt{2\pi\sigma}} e^{-(z-\mu)^2/2\sigma^2}$$

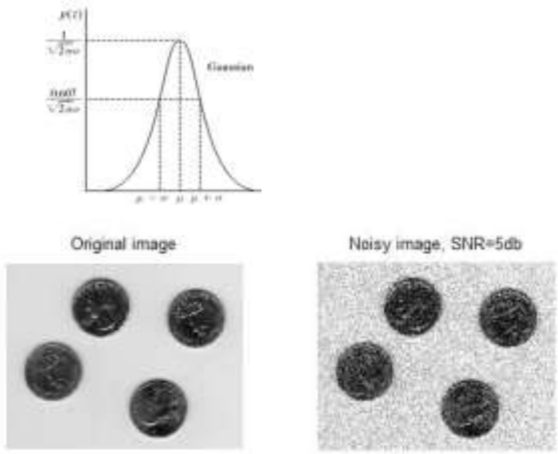

Fig.3 Gaussian noise

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2.4 Quantization noise

Quantization noise is also called as uniform noise. This type of noise appearance is inherent in amplitude quantization process. This type of noise is caused due to conversion of analog data into digital data. In quantization model, signal to noise ratio (SNR) is limited by minimum and maximum pixel value, $p_{min}$and p_{maz} respectively. Its probability density function is given as:

$$p(g) = \begin{cases} \frac{1}{b-a} & if\ a \leq g \leq b \\ 0 & Oherwise \end{cases}$$

2.5 Speckle Noise

Speckle noise is multiplicative noise unlike the Gaussian and salt pepper noise. This noise can be modeled by random vale multiplications with pixel values of the image and can be expressed as

$$P = I + n * I$$

Where P is the speckle noise distribution image, I is the input image and n is the uniform noise image by mean o and variance v.

Speckle noise is commonly observed in radar sensing system, although it may appear in any type of remotely sensed image utilizing coherent radiation. Like the light from a laser, the waves emitted by active sensors travel in phase and interact minimally on their way to the target area. Reducing the effect of speckle noise permits both better discrimination of scene targets and easier automatic image segmentation.

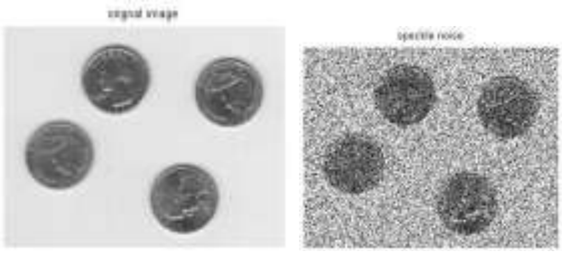

Fig. 4: Speckle Noise

2.6 Structural noise

Structural noise may be periodic, stationary or non-stationary, a periodic, detector striping and detector banding in nature. The periodic Structural noise commonly causes due to interface between electronic components. The structural noise having periodic, no-nstationary in nature has vary in amplitude, frequency and phase [3]. Structural a perodic noise generally created in JPEG noise.

2.7 White noise

In signal processing, white noise is a random signal with a constant power spectral density. The white noise is so named because it’s analogous to white light. In particular each sample has a normal distribution with zero mean, then the signal is said to be Gaussian white noise. In a sample a white noise signal may be sequential in time. In digital image processing, the pixels of a white image are typically arranged in a rectangle grid [4].

2.8 Brownian noise

Brownian noise is given after the name of botanist Robert Brown who discovered Brownian motion in the 1800s. Brown noise has a spectral density that is inversely proportional to its square of frequency [5]. In the other words its power significantly decreases as its frequency increases. As a result brown noise has a lot more energy at low frequency as compare to its higher frequency. Brownian motion is causes due to the random movement of suspended Particles in fluid [6].

III. RELATED WORK

During the procession of acquisition and transmission noises or blurred information is inserted into image which degraded the quality. To enhance the quality of image different authors presented various image restoration methods. In this literature study of them is discussed below:

Gao et al. (2017) [8] they treated the RTI system as an image degraded process, and we propose an estimation model based on mixture Gaussian distribution to derive the degradation function from the shadowing-based RTI model. Then we use this degradation function to recover an original image by a method called constrained least squares filtering. So far, many imaging models have been proposed for localization; however, they do not have a satisfied imaging accuracy. Simulated and experimental results show that the imaging accuracy of our proposed method is improved, and the proposed method can be used in the real-time circumstances. *Bhargava et al. (2017) [9],* In digital imaging, blurring is a bandwidth reduction of the image due to imperfect image construction process which gives poor image quality. Some blurring always arises in the recording of a digital image. Along with these blurring effects, noise always corrupts any recorded image. Reconstructing process is divided into two categories, first is nonblind in which the blurring function is given and the degradation process is inverted using one of the restoration algorithms and second blind where blurring operator is not known. Deconvolution using blind method is very complex process where image recovery is performed with little or no prior knowledge of the degrading PSF. The PSF represent the impulse response of a point source. In this paper Blind Deconvolution method has been implemented to deblur a single image. PSNR and MSE value has been calculated. *Li Yang et.al in 2016 [10]* , the blur which is caused by the relative motion between the camera and object scene is called motion-blur. The blur direction and the motion-blurred image are essential for image restoration, which is degraded by the relative motion. And directly affect subsequent image recognition and image analysis. The recently developed Approach based on a fractional directional derivative operator with non-causal is derived. In order to have a grasp of image restoration from motion-blurred photograph, a partial derivative operator is deduced on the basis of fractional derivative in this paper. According to use of real and synthesized motion blur images quantitative and qualitative performance evaluations are carried out. Noise is the sensitive factor of this method. The experiments based on a non-causal fractional partial derivative mask verified that this method provides better immunity to noise in comparison and accuracy of identifying motion blur than the method based on integer-order differentiation does in particular large blur length. *Tomio goto et.al (2016) [11]*, they proposed a blind method that rapidly restores blurred images using local patches. In this method, a portion of the blurred image is used for PSF (point spread function) estimation. In addition, we propose an automatic PSF size calculation algorithm that generates an autocorrelation map (auto map). Experimental results show that our proposed method generates accurate de-blurred images, and processing time is significantly lower than that of the conventional de-blurring method. *K. Panfilova et.al (2016) [12]*, they considered the problem of image restoration, in particular, linear blur compensation. To restore image we use Lucy-Richardson iterative method and its modifications. The main disadvantages of the basic method are edge artifacts in the form of horizontal and vertical stripes on the image and lack of information about the optimal number of algorithm iterations. To decrease the negative impact of those disadvantages we propose to extend the image beyond its original borders reducing its brightness to zero at new borders, as well as use an empirical criterion to define the point where the iterative Lucy-Richardson procedure should be finished. The criterion is based on certain analysis of the changes in the image at each iteration. The proposed adaptations resulted in decrease of image distortion by more than 50% in terms of r.m.s. metric, making it possible to estimate the number of iterations required for better performance of the algorithm. *Jian-Jiun Ding et.al in (2014) [13]*, In image deblurring, it is important to reconstruct images with small error, high perception quality, and less computational time. In this paper, a blurred image reconstruction algorithm, which is a combination of the Richardson-Lucy (RL) de-convolution approach and a pyramid structure, is proposed. The RL approach has good performance in image reconstruction. However, it requires an iterative process, which costs a lot of computation time, and the reconstructed image may suffer from a ringing effect. In the proposed algorithm, we decompose a blurred image from a coarse scale to a fine scale and progressively utilize the RL approach with different number of iterations for each scale. Since the number of iterations is smaller for the large scale part, the computation time can be reduced and the ringing effect caused from details can be avoided. Simulation results show that our proposed algorithm requires less computation time and has good performance in blurred image reconstruction. *Basak Oztan and Amal Mali et al. (2015) [14]* presented a segmentation-based post-processing method to remove compression artifacts from JPEG compressed document images. JPEG compressed images typically exhibit ringing and blocking artifacts, which can be objectionable to the viewer above certain compression levels. The ringing is more dominant around textual regions while the blocking is more visible in natural images. *Tijana Ružic and Aleksandra Pižurica, et al. (2015) [15]* This approach can be employed to improve the speed and performance of virtually any (patch-based) impainting method. In this paper, we introduced a novel MRF-based impainting method that uses context-aware approach to reduce the number of possible labels per MRF node and choose them in such a way that they better fit the surrounding context. Context is represented within blocks of fixed or adaptive sizes using contextual descriptors in the form of normalized text on histograms. Additionally, to divide the image into blocks of adaptive size, a novel top-down splitting procedure was introduced. *Sing Bing Kang at el(2014) [16]* They first showed that, for natural images, Patch GPs can be effectively approximated by minimum hop paths (MHPs) that generally correspond to Euclidean line paths connecting two patch nodes. To construct the de-noising kernel, we further discretize the

MHP search directions and use only patches along the search directions. Along each MHP, we apply a weight propagation scheme to robustly and efficiently compute the path distance. To handle noise at multiple scales, we conduct wavelet image decomposition and apply Patch GP scheme at each scale. Comprehensive experiments show that our approach achieves comparable quality as the state-of-the-art methods such as NLM and BM3D but is a few orders of magnitude faster. *Emmanuel 2013 [17]* they explored alternative approaches to non-locality, with the goals of i) developing universal approaches that can handle local and non-local constraints and ii) leveraging the qualities of both non-locality and sparsity. For the first point, we will see that embedding the patches of an image into a graph-based framework can yield a simple algorithm that can switch from local to non- local dilusion, which we will apply to the problem of large area image impainting. *Joseph Salmon at el (2013) [18]* in recent years, over complete dictionaries combined with sparse learning techniques became extremely popular in computer vision. While their usefulness is undeniable, the improvement they provide in specific tasks of computer vision is still poorly understood. The aim of the present work is to demonstrate that for the task of image de-noising; nearly state-of-the-art results can be achieved using orthogonal dictionaries only, provided that they are learned directly from the noisy image.

IV.RESTORATION TECHNIQUES

There are various restoration techniques as well as spatial domain filter for noise removal. In spatial domain methods, the technique operates directly on the pixels of an image. The spatial domain methods are used for removing additive noise only. Sometimes blur helps to increase photo’s expressiveness but it decreases the quality of image unintentionally. In image restoration, the improvement in the quality of the restored image over the recorded blurred one is measured by the signal-to-noise ratio improvement. Image restoration techniques are used to make the corrupted image as similar as that of the original image. Figure.3 shows classification of restoration techniques. Basically, restoration techniques are classified into blind restoration techniques and non-blind restoration techniques. Non-blind restoration techniques are further divided into linear restoration methods and non-linear restoration method.

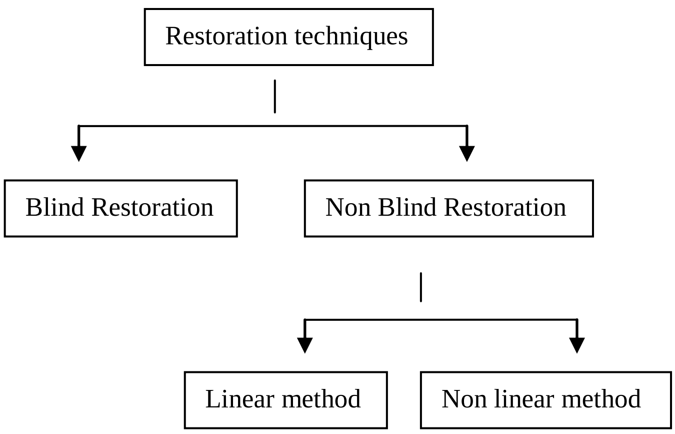

Fig.2 Categorization of Restoration techniques

4.1 Non-blind restoration techniques

A non-blind technique depends on the estimation of PSF which should be priorly known. Based on PSF estimation it restores the input image. As mentioned above other two types of non-blind techniques are linear restoration methods such as Weiner filter, Inverse filter, and Constrained Least square filter. Lucy-Richardson algorithm is a Non-linear type of restoration method.

4.1.1 Weiner Filter

Wiener filter includes both the degradation function and statistical characteristics of noise into the restoration process. The main objective of the method is to find an estimated value of the uncorrupted image value such that the mean square value between them is minimized. The drawback of inverse and pseudo inverse filtering is that they are noise sensitive. But wiener filtering is not noise sensitive .so this is the advantage of the wiener filtering. Its response is better in presence of noise. [19]

Advantages:

If the interference and the signal of interest are Gaussian then the Wiener filter is optimal, nonlinear systems won't help. They are optimal in an information theoretic sense, least squares aren't an arbitrary norm, it falls out of the likelihood.

Disadvantages:

If you don't get much change in noise or signal a fixed filter will be less expensive computationally. It will also be immune to estimation variance; whenever you estimate a stochastic parameter you will add noise to the system. Wiener also isn't set up to deal with mixture distributions (such as Latent Dirichlet Allocation, K-means, and Nonnegative Matrix Factorization can attack). It also isn't set up for discrete state systems like Markov chains.

4.1.2 Inverse Filtering

Direct inverse filtering is the simplest approach to restoration. In this method, an estimate of the Fourier transform of the image f(u,v) is computed by dividing the Fourier transform of the. degraded image by the Fourier transform of the degradation function

$$f(u,v) = \frac{G(u,v)}{H(u,v)}$$

This method works on form when convenient is none additive noise in the degraded image. That is, when the degraded image is given by

$$g(x;y) = f(x;y) * h(x;y)$$

But if noise gets added to the degraded image then the result of direct inverse filtering is very poor. Equation gives the expression for G(u;v) Substituting for H(u;v) in the above equation, we get

$$f(u;v) = f(;v) + \frac{N(u,v)}{H(u,v)}$$

The above equation shows that direct inverse filtering fails when additive noise is present in the degraded image. Because noise is random and so we cannot find the noise spectrum N(u;v). DLR is a non blind technique of image restoration, used to restore a degraded image that has been blurred by a recognized PSF. It is an iterative formula in which the pixels of the observed image are represented using the PSF and the latent image as follows: [20]

Advantages:

The advantage of the inverse filter is that it requires only the blur PSF as a priori knowledge, and that it allows for perfect restoration in the case that noise is absent. Inverse filtered images are therefore often dominated by excessively

amplified noise.

Disadvantages:

The disadvantage of inverse filter is that it will not perform well in the presence of noise. If there is a noise in the image, inverse filter tend to amplify the noise which is undesirable. In the presence of noise, it is better to go for a wiener filter. Second disadvantage, it is not always possible to obtain an inverse

4.1.3 Constraint Least-Square Filter

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 wiener filtering but viewpoint of both the filtering techniques are different. In regularized filtering less previous information is required to apply restoration. The regularization filter is frequently chosen to be a discrete Laplacian. This filter can be understood as an approximation of a Weiner filter.

The second name of filter called Regularized filter is a vector-matrix form of linear degradation model. Equation is [21]:

$$g=H*f+n$$

Where f is M*N vector whose first N elements are first-row pixels of the image, next N elements are second-row pixels up to MN*MN. Now the problem is simple matrix multiplication so now need to find the second deviation of degraded image [22].

Advantages:

This method does not require prior knowledge for the removal of noise and blur. It efficiently removes the blurred and it is mostly like to the weiner filter and it overcome the problem of inverse filter.

Disadvantages:

4.1.4 Lucy- Richardson Algorithm Techniques

The image restoration is divided into blind and non blind de convolution. In non blind PSF is known. The Richardson–Lucy is the most popular technique in the field of astronomy and medical imaging .The reason of popularity is its ability to produce reconstructed images of good quality in the presence of high noise level. Lucy and Richardson found this in the early 1970's from byes theorem. Lucy Richardson is nonlinear iterative method. This method is gaining more acceptance than linear methods as better results are obtained here. The inverse Fourier transform of Optical Transfer Function (OTF) in the frequency domain is the PSF, where OTF gives linear, position-invariant system the response to an impulse. The Fourier transfer of the point (PSF) is OTF[23].

Advantages:

This technique effectively removes the noises and blurs from the image. It helps to overcome the problem of inverse filter.

Disadvantages:

This may have a noise amplification problem and also takes more time in processing than other filter.

4.2 Blind deconvolution techniques

In image processing, blind deconvolution is a deconvolution technique that permits recovery of the target scene from a single or set of "blurred" images in the presence of a poorly determined or unknown point spread function (PSF). [2] Regular linear and non-linear deconvolution techniques utilize a known PSF. For blind deconvolution, the PSF is estimated from the image or image set, allowing the deconvolution to be performed. Researchers have been studying blind deconvolution methods for several decades, and have approached the problem from different directions.

4.2.1 Adaptive Mean Filter

This filter is the third type of spatial domain filters. In Adaptive median filters, the size of the filter can be change. The other filters discussed above can only be used for the images where the density of the noise is less. But this filter is used especially to remove high-density noise from corrupted images.

Advantages:

They have the advantage of satisfactory performance when filtering images having varying content or noise distributions, since they take under consideration the characteristics of the image to be filtered. It is obvious, of course, that the estimation accuracy of such characteristics affects their performance.

The adaptive median filter preserves detail and smooth non-impulsive noise, while the standard median filter does not.

Disadvantages:

This technique is merely used for removing salt and pepper noise while for other it can not work. It also does not remove any kind of blurs.

4.2.2 Order Static Filter

These are the spatial filters whose response is based on the ordering of the pixels contained in the image area and compassed by the filter. The response of the filter at any point is determined by ranking result.

$$F1(x,y)=median\{g(u,v)\}$$

$$F1(x,y)=max\{g(u,v)\}$$

$$F1(x,y)=mean\{g(u,v)\}$$

Advantages:

Effective in the case of Gaussian, speckle, salt and pepper and Poisson noise .

Disadvantages:

The main problem with such filters is the underlying stationary assumption: the derivation of the OSF assumes that X is a stationary point process, an assumption which is grossly violated if there is an edge, line, or other strong signal activity in the window.

4.2.3 Alpha- trimmed mean Filter

Alpha-trimmed mean filter is windowed filter of nonlinear class, its nature is hybrid of the mean and median filters. The basic idea behind filter is for any element of the signal (image) look at its neighborhood, discard the most atypical elements and calculate mean value using the rest of them. Alpha you can see in the name of the filter is indeed parameter responsible for the number of trimmed elements.

Alpha-trimmed mean filter algorithm:

a) Place a window over element.

b) Pick up elements.

c) Order elements.

d) Discard elements at the beginning and at the end of the got ordered set.

e) Take an average — sum up the remaining elements and divide the sum by their number.

4.2.4 Mean Filter

The mean filter is a simple spatial filter. Mean filter acts on an image by smoothing it. The mean filter is a simple sliding window spatial filter that replaces the center value in the window with the average of all the neighboring pixel values including itself. This process is repeated for all pixel values in the image. By doing this, it replaces pixels that are unrepresentative of their surroundings. The window is usually square but it can be of any shape.

8	4	7
2	1	9
5	3	6

This provides a calculated value of 5. The center value is 1, in the pixel matrix and it is replaced with this calculated value 5.

Advantage:

This filter technique is very helpful in removing noise from image at pixel level .

Disadvantages:

This technique is not applicable for salt and pepper noise and also any kind of blur information from image.

V.CONCLUSION

In image processing image restoration is widely used techniques which is very useful for removing noise and blurs from image which is formed during the process of acquisition and transmission. With the addition of these impurities in image it degrades the performance of image. In this paper we presents the literature study about the image restoration and also discusses some techniques of it. After study it is found that the some techniques are removing noises and some are removing blurs so in future work need to design such technique which is suitable for removing both efficiently and consumes less time during processing

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