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PERFORMANCE ANALYSIS OF EFFECTIVE IMAGE RESTORATION TECHNIQUES AT DIFFERENT NOISES

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ABSTRACT

Image processing is one the hot research topic for the researchers. The image obtained from the different sensors or satellites are degraded and are not suitable for human perception or further process. The images are degraded by many parameters like noises in the environment or blurring of the image during image acquisition or during processing of the image. In order to improve the quality of the image so that the required objects can be easily accessible from the sensed images, the image restoration technique is used in the image processing. It improves the objectivity of the image and removes the noise and blurry content in the image. In this paper we are considering four most popular image restoration techniques like Wiener Filter, Lucy-Richardson Method, Blind De-Convolution and regularized filter. The performances of these techniques are evaluated and compared. Different performance parameters are considered to check the efficiency of above mentioned techniques.

KEYWORDS: Image Processing, Image Restoration, Noise, Blur, Degradation. Lucy Richardson, Wiener

Image Processing is a technique to enhance raw images received from sensors placed on satellites, space probes and aircrafts or pictures taken in normal day-to-day life for various applications for which they were first developed. The result obtained by processing is having greater quality with clear visibility of the objects present sensed image. There are two types of images, analog image and digital image. Now days we all preferring digital image processing as it is having more advantages than compare to analog image processing [Anil K Jain, 1989]. Image processing can be used in remote sensing, medical imaging, forensic studies, textiles, material science, military, graphic arts, printing industry, etc. Some of the fundamental steps involved in image processing are image representation, image preprocessing, image enhancement, image restoration, image analysis, image reconstruction and image data compression [R. C. Gonzalez, 1993]. In this paper, a novel approach for image restoration has been explained.

Images are produced to record or display useful information. But due to imperfections in the imaging and capturing process, however, the recorded image invariably represents a degraded version of the original scene [Neelamani R, 2003]. The degradations may have many causes, but the two types of degradations that are often dominant are noise and blurring, each of which introduces peculiar problems in image restoration.Blurring is a form of bandwidth reduction of an ideal image it can be caused by relative motion between the camera and the original scene, or by an optical system that is out of focus. When aerial photographs are produced for remote sensing purposes, blurs are introduced by atmospheric turbulence, aberrations in the optical system, and relative motion between the camera and the ground. Noise can be defined as any undesired information that contaminates an image. The principal sources of noise in digital images arise during image acquisition and/or transmission. The field of image restoration is concerned with the reconstruction or estimation of the corrupted image from a blurred and noisy one. In the use of image restoration methods, the characteristics of the degrading system and the noise are assumed to be known a priori.

In this paper different image restoration techniques like Image Restoration using Lucy Richardson Method, Regularized filter, Weiner filter and Blind De-convolution method are simulated and are compared by using some standard performance parameters like Entropy, Standard Deviation, Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Peak signal to noise ratio (PSNR),Signal to noise Ratio (SNR) and Percentage Fit Error (PFE). The organization of the paper is as follows, section II represents explanation about Image Restoration, its model and different image restoration techniques, section III describes the proposed work, section IV simulation of different image restoration techniques, section V gives results and discussion finally section VI concludes the paper.

IMAGE RESTORATION

Image Restoration is the process of obtaining the original image from the degraded image by using some prior knowledge of degradation phenomenon [CharuKhare, 2012].Image restoration can be used in many different applications such as Scientific areas, Medical applications, Astronomy, Remote Sensing, Forensic Studies, Restoration of Compressed Images, Material Science, Military, Film industry etc. Image Restoration is the operation of taking a corrupted/noisy image and estimating the clean original image. It helps to eliminate and correct errors that do not accurately reflect the original images. It uses digital filtering i.e., used to eliminate dots or image spots. Image Restoration deals with improving the appearance of an image.

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The purpose of image restoration is to compensate for or undo defects [Er.Neha Gulati, 2012]. It improves the visibility of the image. Generally, blurring and noisy digital image formation can be modeled by linear spatial model as shown in Figure 1[Er.Neha Gulati, 2012] [CharuKhare, 2012].

The original input is a two-dimensional image f(x,y). This image is operated on by the system H and after the addition of η(x,y) one can obtain the degraded image g(x,y). Digital image restoration may be viewed as a process in which we try to obtain an approximation to f(x,y) given g(x,y) and H and after applying Restoration filters we obtain restored image $\hat{f}(x,y)$ .The degradation phenomenon is mathematically expressed as [1].

$$g(x,y) = h(x,y) + \eta(x,y)$$

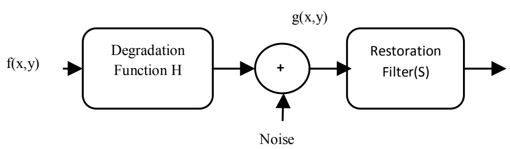


Figure 1: Model of Image Degradation/ Restoration

Image Restoration Techniques

Image restoration is deals with improving the appearance of an image. It is different from image enhancement. Image enhancement is subjective while image restoration is objective. There are various restoration techniques to estimate original signal from the degraded signal, such techniques are listed below.

1. Image Restoration using Lucy Richardson Method.
2. Image Restoration using Regularized filter.
3. Image Restoration using Weiner filter.
4. Image Restoration using Blind De-convolution method.
5. Image Restoration using Inverse filter.
6. Image Restoration using Median Filtering.
7. Image Restoration using Arithmetic Mean Filter.

In this paper we are mainly concentrating on first four methods.

PROPOSED WORK

Images are produced to record or display useful information. Due to imperfections in the imaging and capturing process, however, the recorded image invariably represents a degraded version of the original scene. The undoing of these imperfections is crucial to many of the subsequent image processing tasks. There exists a wide range of different degradations that need to be taken into account, covering for instance noise, geometrical degradations (pincushion distortion), illumination and color imperfections (under/over-exposure, saturation),and blur. The purpose of image restoration is to compensate for or undo these defects and improves the visibility of the image. The noise and blur models that are to be used in this paper are Speckle noise, Gaussian noise and Salt and Pepper noise with motion blur.

Speckle noise: Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar (SAR) images. SAR is caused by unified processing of backscattered signals from multiple distributed targets [Anil Kumar Kanithi, 2011].

Gaussian noise: It represents statistical noise having probability density function (PDF) equal to that of the normal distribution, which is also known as the Gaussian distribution. In other words, the values that the noise can take on are Gaussian-distributed [Anil Kumar Kanithi, 2011]. Principal sources of Gaussian noise in digital images arise during acquisition eg. Sensor noisecaused by poor illumination and/or high temperature, and/or transmission eg. Electronic circuit noise.

Salt and Pepper noise: Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by analog-to-digital converter errors, bit errors in transmission, etc [Anil Kumar Kanithi, 2011].

Motion Blur: motion blur is due to relative motion between the recording device and the scene. This can be in the form of a translation, a rotation, a sudden change of scale, or some combinations of these. The Motion Blur effect is a filter that makes the image appear to be moving by adding blur in a specific direction [CharuKhare, 2011][Aizenberg I, 2002].

In this paper the Following techniques are used to restore a noisy and blur images.

A. Image Restoration Using Lucy Richardson Method:

Lucy Richardson algorithm is also known as Lucy Richardson De-convolution, it is an iterative procedure for recovering a latent image that has been blurred by a known Point Spread Function (PSF). Use the deconvlucy function to de-blur an image using the accelerated, damped, Lucy-Richardson algorithm. This function can be effective when you know the PSF but know little about the additive noise in the image. Pixels in the observed image can be represented in terms of the point spread function and the latent image as [CharuKhare, 2011]:

$$di = \sum_j p_{ij} uj$$

Where p_{ij} is the point spread function (the fraction of light coming from true location j that is observed at position i), u_{ij} is the pixel value at location j in the latent image, and d_i is the observed value at pixel location i.

The basic idea is to calculate the most likely u_j given the observed d_i and knownp_{ij}. This leads to an equation for u_j which can be solved iteratively according to,

$$u_j^{(t+1)} = u_j^{(t)} \sum_i \frac{d_i}{c_i} p_{ij}$$

Where, $c_i = \sum_j p_{ij} u_j^{(t)}$

It has been shown empirically that if this iteration converges, it converges to the maximum likelihood solution foru_j [Amandeep Kaur, 2012].

B. Image Restoration Using Regularized Filter:

Regularized de-convolution can be used effectively when constraints are applied on the recovered image and limited information is known about the additive noise. The blurred and noisy image is restored by a constrained least square restoration algorithm that uses a regularized filter. Ituses the deconvreg function to de-blur an image using a regularized filter. A regularized filter can be used effectively when limited information is known about the additive noise [AdmoreGota, 2013].

C. Image Restoration Using Weiner Filter:

Wiener filter's working principle is based on the least squares restoration problem. It is a method of restoring image in the presence of blur and noise. The Wiener filtering is optimal in terms of the mean square error. In other words, it minimizes the overall mean square error in the process of inverse filtering and noise smoothing [Swati Sharma, 2013]. The Wiener filtering is a linear estimation of the original image [R. C. Gonzalez, 1993]. The Wiener filter minimizes the mean-squared error given by,

$$e^2 = E[(f(x,y) - \hat{f}(x,y))^2]$$

Where, E[ ] is the expected value of the expression, $f(x,y)$ is the original image and, $\hat{f}(x,y)$ is the restored image.

The frequency-domain expression for the Wiener filter is,

$$G(k,l) = \frac{H^*(k,l)}{|H(k,l)|^2 + S_u(k,l)/S_x(k,l)}$$

Where, H(k,l) =Point Spread Function, $S_x(k,l)$ = Signal Power Spectrum, $S_u(k,l)$ =Noise Power Spectrum.

D. Image Restoration Using Blind De-Convolution Method:

The blind deconvolution algorithm can be used effectively when no information about the distortion (blurring and noise) is known. 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). Blind deconvolution can be performed iteratively, whereby each iteration improves the estimation of the PSF and the scene.

In this technique firstly, we have to make an estimate of the blurring operator i.e. PSF and then using that estimate we have to deblur the image. This method can be performed iteratively as well as non-iteratively. In iterative approach, each iteration improves the estimation of the PSF and by using that estimated PSF we can improve the resultant image repeatedly by bringing it closer to the original image [DeepaKundur, 1998].

The blind deconvolution is expressed as,

$$g(x,y) = f(x,y)^* h(x,y)$$

$$g(x,y) = \sum_{(n,m)} f(n,m) h(x-n, y-m)$$

Where, '*' denotes the two dimensional linear convolution operator, g(x,y)= Degraded image, f(x,y)= Original image, h(x,y)= Point spread function, Z = Set of integer number.

SIMULATION

In this case we are considering four image restoration techniques i.e., image restoration using Richardson and Blind De-convolution method and using Weiner and regularized filter. These techniques are simulated in MATLAB 7.8(2009R) version. The steps required in the simulation of each technique are mentioned below.

Algorithm for Lucy Richardson Method

- Read an image into the MATLAB workspace
- Create the noise using imnoise(I,speckle,0.04)
- Create the PSF using PSF = fspecial('Motion', Len, Theta)
- Create a simulated blur in the image and add noise using command *imfilter*
- Use de-convlucy to restore the blurred and noisy image, specifying the PSF used to create the blur,

and limiting the number of iterations to 5 (the default is 10).

Algorithm for Restoration using Regularized Filter

- Read an image into the MATLAB workspace
- Create the noise using imnoise(I,speckle,0.04)
- Create the PSF using PSF = fspecial('Motion', Len, Theta)
- Create a simulated blur in the image and add noise using command *imfilter*
  - Calculating the noise power of the original image
  - Use deconvreg to de-blur the image, specifying the PSF used to create the blur and the noise power, NP.

Algorithm for Restoration using Weiner Filter

- Read an image into the MATLAB workspace
- Create the noise using imnoise(I,speckle,0.04)
- Create the PSF using PSF = fspecial('Motion', Len, Theta)
- Create a simulated blur in the image and add noise using command *imfilter*
- Estimating the noise to signal ratio by specifying the variance of noise and true image.
- Use deconvwnr to restore the blurred and noisy image.

Algorithm for Restoration using Blind De-convolution Method

- Read an image into the MATLAB workspace
- Create the noise using imnoise(I,speckle,0.04)
- Create the PSF using PSF = fspecial('Motion', Len, Theta)
- Create a simulated blur in the image and add noise using command *imfilter*
- De-blur the image using deconvblind, making an initial guess at the size of the PSF.
- Create a WEIGHT array to exclude areas of high contrast from the de-blurring operation. This can reduce contrast-related ringing in the result.
- Refine the guess at the PSF
- Rerun the de-convolution, specifying the WEIGHT array and the modified PSF. The restored image has much less ringing around the image.

RESULTS

Nomenclature

I_r, I_f: Representation of reference/source image and fused/restored image.

M, N: Representation of size/pixel values of the image.

Entropy

Entropy is used to measure the information content of an image. It is sensitive to noise and other unwanted fluctuations. An image with high information content will have high entropy [V.P.S. Naidu, 2008].

Standard Deviation

It is known that std. deviation is composed of the signal and noise parts. This metric would be more efficient in the absence of noise. It measures the contrast in the restored image. An image with high quality contrast would have a high standard deviation [V.P.S. Naidu, 2008].

$$Std.dev(\sigma) = \sqrt{\frac{1}{MN}\sum_{y=0}^{N-1}\sum_{x=0}^{M-1}\left[I_f(x,y) - U_{1f}\right]^2}$$

RMSE

Computed as the root **Mean Square Error** of the corresponding pixels in reference and restored image [V.P.S. Naidu, 2008].

$$RMSE = \sqrt{\frac{1}{NM}\sum_{i=1}^{M}\sum_{j=1}^{N}(I_r(i,j) - I_f(i,j))^2}$$

Mean Absolute Error (MAE)

In statistics, the mean absolute error (MAE) / Normalized Error is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. The mean absolute error is given by [V.P.S. Naidu, 2008].

$$MAE = \frac{1}{NM}\sum_{i=1}^{M}\sum_{j=1}^{N}(I_r(i,j) - I_f(i,j))^2$$

Peak Signal to Noise Ratio (PSNR)

PSNR analysis uses a standard mathematical model to measure an objective difference between two images. It estimates the quality of a reconstructed image with respect to an original image. The basic idea is to compute a single number that reflects the quality of the reconstructed image. Reconstructed images with higher PSNR are judged better [V.P.S. Naidu, 2008].

$$PSNR(dB) = 20\log\frac{L^2}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(I_r(i,j) - I_f(i,j))^2}}$$

SNR

Computed as the Signal to Noise Ratio of the corresponding pixels in reference and restored images. Its value will be higher when reference image and restored image are alike. Higher value implies better restoration [V.P.S. Naidu, 2008].

$$SNR = 20\log_{10}\left(\frac{\sum_{i=1}^{M}\sum_{j=1}^{N} I_r(i,j))^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}(I_r(i,j) - I_f(i,j))^2}\right)$$

Percentage Fit Error (PFE)

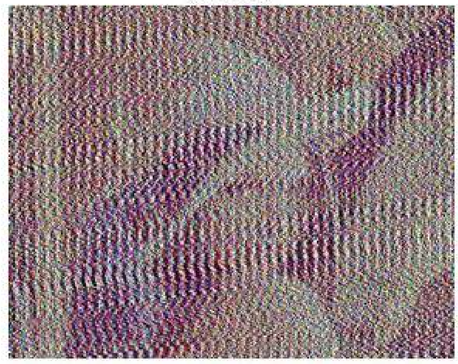
Computed as the norm of the difference between the corresponding pixels of reference and restored image to the norm of the reference image. This will be zero when both reference and restored images are exactly alike and it will be increased when the restored image is deviated from the reference image [V.P.S. Naidu, 2008].

$$PFE = \frac{norm(I_r - I_f)}{norm(I_r)} * 100$$

Scene 1: Leena.png, Noise=Speckle, Blur=Motion

Source image Image with Speckle Noise and Blur

LR Restored Image Reg.. Restored Image



Weiner Restored Image Blind De-convolution Restored Image

Fig2: Reconstructed images of Leena using speckle noise as additive noise

Noise=Gaussian, Blur=Motion

Image with Gaussian Noise and Blur
LR Restored Image

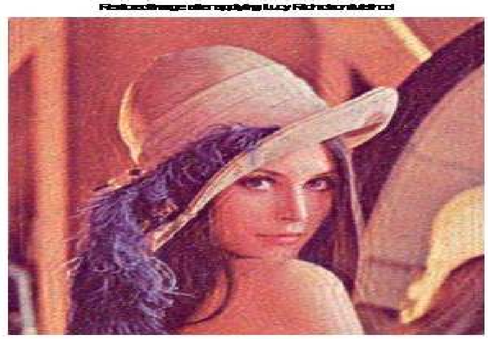
Regularized Filter Restored Image
Weiner Restored Image

Blind De-convolution Restored Image

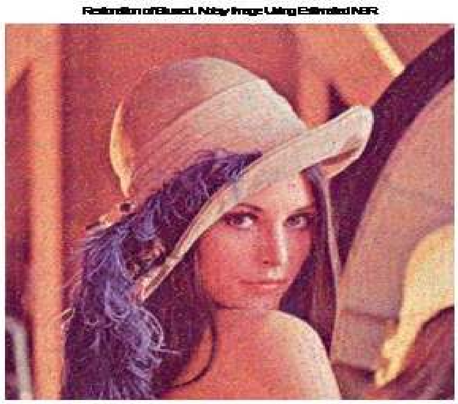
Figure 3: Reconstructed images of Leena using Gaussian noise as additive noise

Noise=Salt and Pepper, Blur=Motion

Image with Salt and Pepper Noise and Blur
LR Restored Image



Regularized Filter Restored Image
Weiner Restored Image



Blind De-convolution Restored Image

Figure 4: Reconstructed images of Leena using Salt and Pepper noise as additive noise

Performance Analysis

Here we are going to decide which method is suitable for image restoration for different types of noise.

Scene 1: Leena.png, Noise=Speckle, Gaussian, Salt and pepper, Blur=Motion

Table 1: Performance evaluation metrics to evaluate image restoration with Speckle noise for Lenna image

	Lucy R	Regularized	Weiner	Blind De-conv
Entropy	7.7671	3.7805	**7.7984**	7.7335
Std. Dev	22.7454	23.084	23.0668	**57.1614**
RMSE	**0.0033**	0.5684	0.0050	0.5093
MAE	0.03733	0.2343	**0.0326**	0.0454
PSNR	**48.4828**	25.8187	48.2150	15.1538
SNR	47.2751	36.4447	**47.7903**	46.9347
PFE	1.9833	29.9710	**1.7067**	10.5749

Table 2: Performance evaluation metrics to evaluate image restoration with Gaussian noise for Lenna image

	Lucy R	Regularized	Weiner	Blind De-conv
Entropy	7.7604	3.6722	**7.7942**	7.7765
Std. Dev	22.9086	23.212	23.2237	**57.4181**
RMSE	**0.0038**	0.5759	0.0057	0.4635
MAE	0.04688	0.2413	0.0390	**0.0330**
PSNR	**47.6615**	26.0315	47.1006	15.8107
SNR	46.6787	36.4075	**47.4561**	47.3119
PFE	9.8234	27.1545	**9.5243**	16.2349

Table 3: Performance evaluation metrics to evaluate image restoration with Salt and pepper noise for Lenna image

	Lucy R	Regularized	Weiner	Blind De-conv
Entropy	7.7723	3.4710	**7.7970**	7.7900
Std. Dev	22.5707	23.443	23.0316	**57.6275**
RMSE	**0.0034**	0.5626	0.0058	0.5270
MAE	0.0392	0.2369	**0.0344**	0.0519
PSNR	**46.5171**	25.8034	46.1830	14.8199
SNR	47.1121	36.4740	**47.1938**	46.7982

CONCLUSION

This paper has demonstrated the various restoration techniques that have been developed to restore the original image from the degraded image. To summarize, it is concluded that filters are an important engineering technique which help to produce a good quality image by removing noises from an image which are bound to creep into an image because of various reasons which may be controllable or sometimes uncontrollable. Here mainly four techniques have been simulated and compared. The results show that the performance by the LR Weiner filter is good, but the performance of Regularized filter is worst in case of all types of noises. The performance of Blind de-convolution is good compared to regularized filter and poor when compared with Weiner and Lucy Richardson methods.

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