Restoration and Comparisons of Gaussian Blurred-Noisy Image Using Different Filtering Techniques

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Abstract: ***This paper attempts to restore dental image degraded with blur and noise using different de-blurring filters. The image is degraded by the combination of Gaussian blur and Salt & Pepper /Speckle / Poisson / Gaussian noise for different values of PSF. All the degraded images are then restored using Wiener Filter (zero NSR and Estimated NSR), Regularized Filter, Lucy Richardson Filter technique. The restored images are then compared on the basis of PSNR and MSE values. This comparison are made to find which filter technique removes which combination of blur and noise on what value of PSF with high PSNR and low MSE value.***

Keywords: Gaussian Blur, PSF (Point Spread Function), Wiener Filter, Regularized Filter, Lucy-Richardson method, PSNR, MSE

1. Introduction

Image restoration is the operation of taking a corrupted/noisy image and estimating the clean original image. Corruption may come in many forms such as blur, noise and camera mis-focus. The purpose of image restoration is to "compensate for" or "undo" defects which degrade an image. In cases like blur, it is possible to come up with an very good estimate of the actual blurring function and "undo" the blur to restore the original image. In cases where the image is corrupted by noise, the best we may hope to do is to compensate for the degradation it caused. The area of image restoration (sometimes referred to as image de-blurring or image de-convolution) is concerned with the reconstruction or estimation of the uncorrupted image from a blurred and noisy image. Essentially, it tries to perform an operation on the image which is the inverse of the imperfections in the image formation system.

Image noise is an undesirable by-product of image capture that adds spurious and extraneous information. The presence of noise gives an image mottled, grainy, textured or snowy appearance. Blurring an image usually make image un-focused. Blurring is caused by movement during image capture by camera, long and short exposures times, atmospheric turbulence, use of a wide angle-lens, out-of-focus optics, scattered light distortion in confocal microscopy.

The restoration of degraded image can be achieved by using de-blurring filters. Removal of blur and noise from the degraded image requires the knowledge of PSF (point spread function). With the knowledge of PSF, we can determine the quality of original image. When we have the knowledge of PSF, the blurred image can be restored by using Wiener filtering, regularized filtering and Lucy-Richardson algorithm.

The proposed methodology consists of two models:

1. Degradation Model
2. Restoration Model

2. Degradation Model

In degradation model, the original image is blurred using degradation function and additive noise [1]. The degraded image is described as follows:

$g = h * f + n$ (1)

In equation (1), g is the degraded image, h is the degradation function or PSF or blur kernel, f is an original image and n is the additive noise, '*' is the convolution operator.

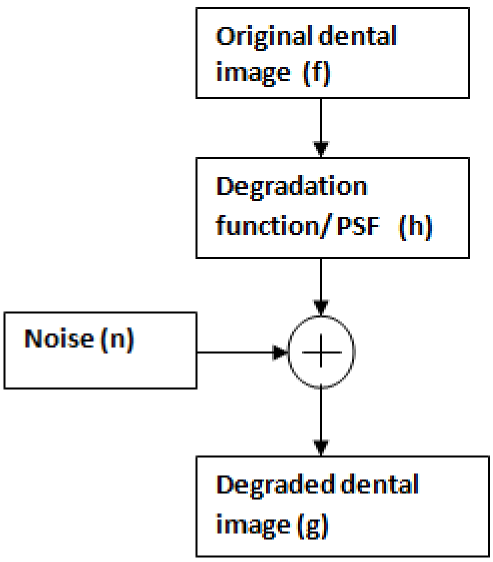


Figure 1: Degradation Model

a. Blurring

A blur in an image is a shape or area which you cannot see clearly because it has no distinct outline or because it is moving very fast. The Blur effects are filters that smooth transitions and decrease contrast by averaging the pixels next to hard edges of defined lines and areas where there are significant colour transition [2].

b. Blurring Types

In Digital Image Processing, there are three types of blur effects:

1. Average Blur: The Average Blur effect smoothes the active layer or selection by softening hard edges .Each pixel value in an image is replaced with the average value of its neighbors, including that pixel [3].

Average blurring can be distributed horizontally and vertically and can be circular averaging by radius R which is evaluated by the formula [2]:

R=square root (g^2 + f^2) (2)

In equation (2),g is the horizontal size blurring direction f is vertical blurring size direction R is the radius size of the circular average blurring.

2. Gaussian Blur: The Gaussian Blur effect smoothes the active layer or selection by averaging pixels using a weighted curve.

The weights are chosen according to the shape of Gaussian function [3]. The Gaussian Blur effect is a filter that blends a specific number of pixels incrementally, following a bell-shaped curve. Blurring is dense in the centre and feathers at the edge.

3. Motion Blur: Motion blur is the apparent streaking of rapidly moving objects in a still image or a sequence of images such as a movie or animation.

The Motion Blur effect is a filter that makes the image appear to be moving by adding blur in a specific direction [2].

c. Point Spread Function (PSF)

Point Spread Function (PSF) is the degree to which an optical system blurs (spreads) a point of light.

Point Spread Function adds blur to an image. The blur was implemented by first creating a PSF filter in MatLab that would approximate Gaussian blur. This PSF was then convolved with the original image to produce the blurred image.

The amount of blur added to original image depended on two parameters of PSF:

i. length of blur (in pixels)
ii. Angle of the blur.

These attributes were altered to generate different amounts of blur [4].

d. Noise

Noise, in an image, is any degradation in an image signal, caused by external disturbance while an image is being sent from one place to another place via satellite, wireless and network cable. Noise is the result of errors in the image acquisition process that result in pixel values that do not reflect the true intensities of the real scene.

e. Types Of Image Noise

There are four types of noises that can be added to an image:

1. Salt & Pepper Noise: It is also known as impulsive noise. It represents itself as randomly occurring white and black pixels. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions [5].

The corrupted pixels are either set to the maximum value or have single bits flipped over. In some cases, single pixels are set alternatively to zero or to the maximum value, giving the image a `salt and pepper' like appearance [5].

2. Speckle Noise: Speckle is a granular 'noise' that inherently exists in and degrades the quality of the active radar, synthetic aperture radar (SAR), and medical ultrasound images[5].

It is multiplicative noise unlike the Gaussian or Salt and Pepper type noise. Random values get multiplied with pixel values of an image.

3. Poisson Noise: It is also known as Photon noise. Poisson noise is a basic form of uncertainty associated with the measurement of light, inherent to the quantized nature of light and the independence of photon detections.

Its expected magnitude is signal dependent and constitutes the dominant source of image noise except in low-light conditions.

4. Gaussian Noise: Gaussian noise is one type of noise which is evenly distributed over the 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 probability density function (PDF) of Gaussian noise is equal to that of the normal distribution, also known as Gaussian distribution.

3. Restoration Model

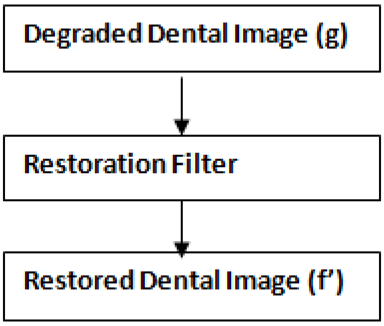


Figure 2: Restoration model

In Restoration model, the degraded image is reconstructed using restoration filters. We get an estimate of the original image as a result of restoration. The closer the estimated image (f') is to the original image the more efficient is our restoration filter.
The three restoration filters used here are:

1. Wiener Filter**:** The Wiener filter is a filter used to produce an estimate of a desired or target process by linear time-invariant filtering of an observed noisy process.

The Wiener filter is the MSE-optimal stationary linear filter for images degraded by additive noise and blurring. . In the absence of noise, the Wiener filter reduces to the ideal inverse filter.

2. Regularized Filter: Regularized filtering is used when constraints like smoothness are applied on the recovered image.

The blurred and noisy image is regained by a constrained least square restoration algorithm.

3. Lucy-Richardson Method: The Lucy–Richardson de-convolution, is an iterative procedure.

It recovers an image that has been blurred by a known point spread function but with little or no information is available for the noise. The Lucy-Richardson algorithm is derived from counting statistics by means of maximizing the likelihood of the solution.

4. Performance Parameters

In order to compare the restoration techniques of different filters for different blurs and noise, some parameters are considered to distinguish the restoration techniques.

i. MSE (Mean Square Error): It compares the "true" pixel values of our original image to our degraded image. The MSE represents the average of the squares of the "errors" between our actual image and our noisy image.

Error= abs (A-B) (3)
MSE= sqrt(mean(mean(Error.^2))) (4)

In equation (3), Error is the difference between the absolute value of A and B,A is the filtered image and B is the original image.

ii. PSNR (Peak Signal-to-Noise Ratio):It is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. The PSNR is usually expressed in terms of the logarithmic decibel scale.

PSNR=20log10(R/sqrt(MSE)) (5)

where, R is maximum value of the pixel present in an image, MSE is mean square error between the original and de-noised image .

5. Experiments and Results

All implementation work is done in MATLAB R2010a. First of all an original dental image (Fig. a) is blurred with Gaussian Blur with different values of length and angle of blur. Then Salt & Pepper noise is added to it. The three filters are applied to each degraded image. Resulting restored image is compared on PSNR and MSE values.

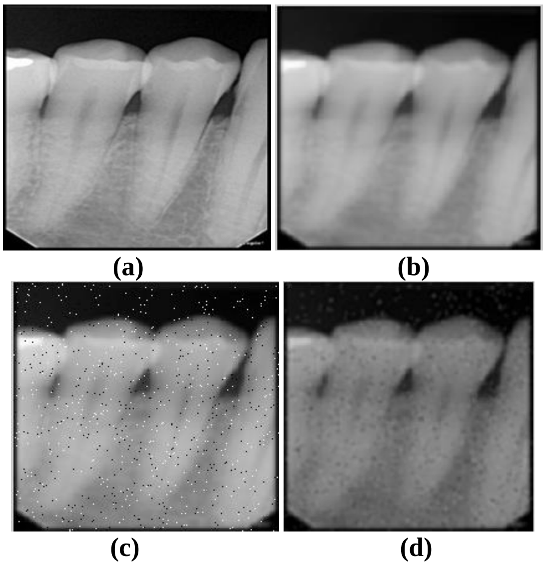
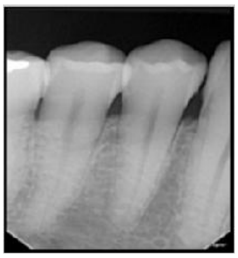


Figure 3: (a) Original image (b) Gaussian blurred image with length=40 and angle=2 (c) Salt & Pepper noise added (d) restored using Wiener filter with estimated NSR

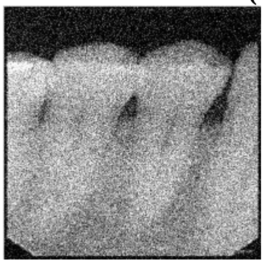
It is found that Wiener filter with estimated NSR (0.3290) restores Gaussian blurred with salt & pepper noisy image with highest PSNR and lowest MSE value. Results are best when length of blur varies from 5 to 50 and angle of blur is equal to 2. PSNR value ranges from 64.7460 dB to 64.9311 dB and MSE value ranges from 0.206 to 0.210.

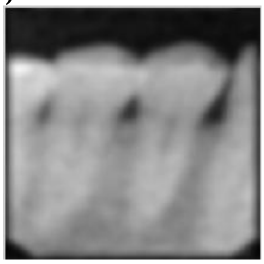
In Figure 3 (d) PSNR=64.9278dB and MSE=0.209.

Now, Gaussian noise is added to the Gaussian blurred image. Out of the three filters, Regularised filter restored the degraded image partially than the other filters. When length of blur varies from 2 to 5 and angle of blur can be any value between 2 to 15, Regularised filter will have high PSNR values ranging from 71.7391 dB to 70.9788 dB and MSE value ranging from 0.0040 to 0.0055.



(e)





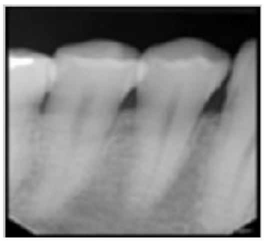
(f) **(g)**

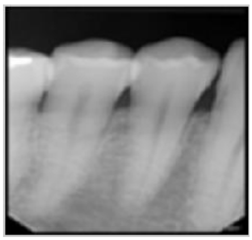
Figure 4: (e) Gaussian blurred image with length=2 and angle=14 (f) Gaussian noise is added (g) restored image by regularised filter

In Figure 4 (g) PSNR value=71.7237 and MSE value=0.044.

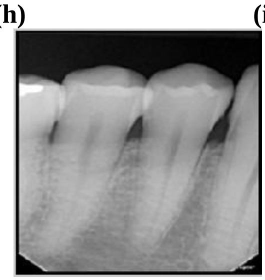
It is found that when Poisson noise is added to Gaussian blurred image, Wiener filter(zero NSR) and Lucy-Richardson filter performs better.

When length of blur varies from 2 to 10 and angle of blur varies between 2 to 10, Wiener filter(zero NSR) gives high PSNR values ranging from 114.7415 dB to 107.4568 dB and MSE value ranges from 2.1824e-007 to 1.1679e-006. When length of blur varies from 2 to 20 and angle of blur varies from 10 to 15, Wiener filter(zero NSR) gives high PSNR values ranging from 100.2714 dB to 118.8024 dB and MSE value ranges from to 6.1086e-006 to 8.5673e-008.





(h) **(i)**

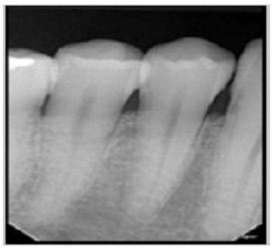


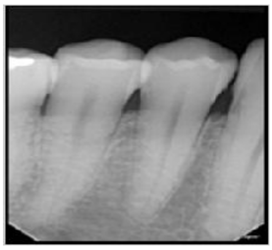
(j)

Figure 5: (h) Gaussian blurred image with length=5 and angle=10 (i) Poisson noise is added (j) restored image by Wiener filter(zero NSR)

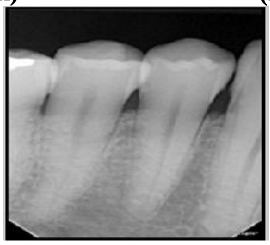
In Fig.5 (j) High PSNR is achieved i.e. 118.8024 dB and lowest MSE value=8.5672e-008.

Since Lucy-Richardson method is an iterative procedure, therefore results are dependent on iterations. Increasing iterations increases PSNR values. When length of blur varies from 2 to 30 and angle of blur is equal to 2, PSNR values ranging from 79.2794 dB to 108.9943 dB and MSE values ranging from7.6761e-004 to 8.1973e-007 is achieved. Further increasing length, angle causes ringing effects in the image with increasing iterations.





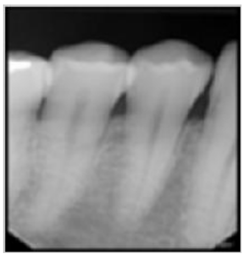
(k) **(l)**

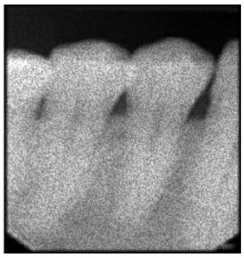


(m)

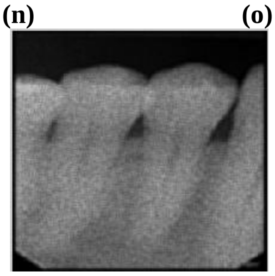
Figure 6: (k) Gaussian blurred image with length and angle is equal to 2 (l) Poisson noise is added (m) restored image by Lucy-Richardson method of iteration=50 with highest PSNR=108.9943 dB and MSE=8.1973e-007.

When Speckle noise is added to Gaussian blurred image, Wiener filter (estimated NSR) results better. It is found that Gaussian blur of length = 4 ,5 and angle varies between 2 to 15, PSNR ranging from approximately 65 dB to 66 dB and MSR ranging 0.203 to 0.205 is achieved.





(n) **(o)**



(p)

Figure 7: (n) Gaussian blurred image with length=5 and angle=15 (o) speckle noise is added (p) restored image by wiener filter with PSNR=65.0409 dB and MSE=0.0204.

Gaussian Blur + Salt & Pepper noise	
5 ≤ Length ≤ 50	Angle=2
Wiener Filter (estimated NSR)	
64.7460 dB ≤ PSNR ≤ 64.9311 dB	
0.206 ≤ MSE ≤ 0.210	

(a)

Gaussian Blur + Gaussian noise	
2 ≤ Length ≤ 5	2 ≤ Angle ≤ 15
Regularized Filter	
70.9788 dB ≤ PSNR ≤ 71.7391 dB	
0.0040 ≤ MSE ≤ 0.0055	

(b)

Gaussian Blur + Poisson noise	
2 ≤ Length ≤ 10	2 < Angle < 10
Wiener Filter (zero NSR)	
107.4568 dB ≤ PSNR ≤ 114.7415 dB	
8.5673e-008 ≤ MSE ≤ 6.1086e-006	
Lucy-Richardson method	
2 ≤ Length ≤ 30	Angle=2
79.2794 dB ≤ PSNR ≤ 108.9943 dB	
8.1973e-00 ≤ MSE ≤ 7.6761e-004	

(c)

Gaussian Blur + Speckle noise	
4 ≤ Length ≤ 5	2 < Angle < 15
Wiener Filter (estimated NSR)	
65 dB ≤ PSNR ≤ 66 dB	
0.203 ≤ MSE ≤ 0.205	

(d)

Table.1 (a), (b), (c), (d) shows the summary of restoration of Gaussian blurred image with different noises by three different filters.

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