Image Restoration From Uniform Motion Blur and Poissonian Noise

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ABSTRACT

Image restoration is to improve the quality of a digital image which has been degraded due to various phenomena like blur, noise. An image with uniform motion blur and Poisson noise is considered. Images acquired at different exposure times are obtained and SNR values for each image are calculated. The blurred and noisy images are restored using the pseudo-inverse filter and SNR values are calculated. The images are then analyzed using the Fourier analysis. The RMSE (Root Mean Square Error) values are obtained. The exposure time at which the restoration performance is better, is considered to be the optimal exposure time which results in the better image quality.

Index Terms

Direct Inverse Filter , Fourier Domain Analysis, Image restoration, Optimum exposure time.

1. INTRODUCTION

The blur and the noise are the inter-related concepts when considering an image. Image quality is the characteristics of an image that measures the acquired image degradation, compared to that of an ideal image. Imaging systems may introduce different types of distortion or artifacts, thus the quality assessment has become an important problem taking several factors into consideration like exposure time, noise, dynamic range etc., Exposure time is the one of the factor that affects the quality of an image. Images may be blurred or noisy due to improper or incorrect exposure times. Uniform motion blur is a blur that affects an image due to the translational motion between the camera and the scene during the image acquisition process. The exposure time is the time that the shutter is open to capture a scene. We are concerned about the restoration of images from uniform motion blur which is a convolution of point spread function (PSF).

Early works were considered about the restoration of images under blurred and noisy conditions by comparing the images, with the known point spread functions (PSFs) by means of blur extent and its direction in which it is extended [15]. This method considers about the uniform motion blur and Poisson noise in blind image restoration techniques [11], [13]. Uniform motion blur has been also considered in blind restoration algorithms [10].

In recent years uniform motion blur is of interest and research is going on in the area that how does the performance of the restoration techniques varies as the various uniform motion blurred images are considered [12]. The blur and the noise are both governed by a single parameter known as the exposure time [6]. With the incorrect setting of the exposure time, the blur and the noise are inversely proportional to one another. i.e., as the blur increases, noise decreases and as the noise increases, blur decreases. Long exposure time increases the blur and the short exposure time increases the noise of an image [14]. Hence a correct exposure time has to be set. The accelerometers in a digital camera cannot sense the uniform motion causing blur and thus a uniform blurred image is obtained [5]. Hence these pictures have to be restored.

Since the blur and the noise are inter-related, we introduce an image model describing this concept. This method can be applied to raw data for best results. Our proposed work aims at attaining an optimal exposure time. Optimal exposure time is the time for which the restored image quality can be increased. This can be done using any of the image restoration techniques. This exposure time values may change according to the amount of blur and noise present in an image. For the images that are noise free and blur free, may have the similar optimal exposure time values. In an image restoration process, the optimal exposure time is the time at which the blur and noise is present at the same amount and thus the quality of an image is increased.

The image model [2] is presented in section II followed by the image restoration in section III, Fourier domain analysis in section IV, and the optimal exposure time in section V.

2. IMAGE MODEL

An image Z_T is modeled with an exposure time of T as shown below,

$$z_T(x) = k(u_T(x) + \eta(x))$$
(1)

Here K is the scaling factor and is always k>0. This factor is scaled to the signal or image components so as to make the information into a usable allowable range i.e., for normalization η(x) is the poisson noise and the $u_T(x)$ is the uniform motion blur. The quantum efficiency (η) of a digital sensor is always greater than zero.

A. Uniform Motion Blur:

The uniform motion blur is modeled hers as,

$$\int_{R^2} h_T(s)ds = T$$
(2)

i.e., the PSF of a uniform motion blur is equaled to its exposure time in this contribution. A PSF is the phenomenon that explains how long or how the blur is spread over an image. Always a blur has a unit mass. In our model it is assumed to have the value of the exposure time. In general the blurred image is a convolution of an object and its PSF.

B. Poisson noise:

The noise is introduced in terms of mean and the standard deviation. Thus it can be re-written as,

$$z_T(x) = E\{z_T(x) + std\{z_T(x)\}\alpha(x)$$

(3)

Where α(x) is a random variable, with zero mean and unitary variance. The mean and the standard deviation is given by the equation,

$$E\{z_T(x)\} = kE\{u_T(x)\}$$

(4)

$$std\{z_T(x)\} = k\sqrt{\operatorname{var}\{\{u_T(x)\} + \operatorname{var}\{n(x)\}\}}$$

(5)

C. SNR:

The SNR is influenced by the exposure time as the ratio between the mean and the standard deviation of noise. It is given by,

$$SNR(z_T(x)) = \frac{E\{Z_T(x)\}}{std\{z_T(x)\}} \overset{\cup}{\cap} \sqrt{\lambda T} \rightarrow \infty$$

(6)

The above equation is applicable for large exposure time. The symbol $\overset{\cup}{\cap}$ denotes that both the terms are strictly bounded between the two positive constants,

When T is small, the SNR is given by,

$$SNR(z_T(x)) = \frac{E\{Z_T(x)\}}{std\{z_T(x)\}} \overset{\cup}{\cap} T^{\beta} \rightarrow 0$$

(7)

Where, β=0.5 or 1.

When the blur increases or when the blur is much large enough increasing along with the exposure time, the restoration does not necessarily be accurate. The phenomenon of restoration suits the best for the blur effects due to the uniform motion blur making the SNR (Z_T) a meaning factor of the restoration quality. With the increasing blur effects along the increase in exposure time makes the restoration a more challenging factor.

3. IMAGE RESTORATION

Diagonal inversion technique is best suited for the image inversion. Here a pseudo-inverse filter is used. A pseudo-inverse filter operates by pixel wise. First the image is divided into several blocks. These blocks are then operated block wise. Each block is restored separately. The appropriate weights are added to the degraded blocks so as to restore them. All the blocks are restored separately by adding the appropriate weights. Finally the blocks are integrated to get the restored images. Thus the images are restored using the pseudo-inverse filter.

Direct inverse filter attempts to recover the original image from the observed blurred image. This type of filters leads to significant errors in the restored image, when the PSF≈0. At this stage, noise gets amplified and the restoration becomes inefficient. The restored images appear to be noisy and may not be restored accurately. Hence these types of filters are not much used in practice. Mostly the PSF function equals to zero at high frequencies. This leads to large amplification of noise that dominates over an image. This amplification leads to significant errors in the restored image. To avoid these problems a pseudo-inverse filter is used.

The pseudo-inverse filtering method provides acceptable results for restoring degraded images. A threshold value is used for this type of filter and reasonable results can be obtained. In pseudo-inverse filtering images are divided into blocks. Then each pair of pixels is operated by adding the compensating weights to the degraded pixels. Thus the pixels are restored and such operation is carried out for each blocks. Then the images are restored.

The transfer function of a pseudo-inverse filter is given by,

$$\frac{1}{H} = \begin{cases} \dfrac{1}{H} & if\ H > \varepsilon \\ \varepsilon & if\ H \le \varepsilon \end{cases}$$

(8)

The value of ϵ affects the restored image .With proper selection of ϵ , the restored image quality lies. It is a small positive threshold value (0.05).

4. FOURIER DOMAIN ANALYSIS

Rather than time domain, frequency domain is the domain for the analysis of mathematical functions and signals respect to frequency. Signals represented in Fourier domain also has the information about the phase shift that is applied to each sinusoidal signals so as to recover the original time signals by recombining the frequency components. The image position changes in the frequency domain correspond to the changes in the spatial domain, representing the rate at which image intensity values are changing in the spatial domain image. The Fourier domain transforms the image to its frequency representation, compute inverse transform back to the spatial domain. In this domain, high frequencies correspond to pixel values those changes rapidly across the image (e.g. text, texture, leaves, etc.). Strong low frequency components correspond to large scale features in the image (e.g. a single, homogenous object that dominates the image).

The Fourier transform is a representation of an image as a sum of complex exponentials of varying magnitudes, frequencies, and phases. The Fourier transform plays a critical role in a broad range of image processing applications, including enhancement, analysis , restoration, and compression. The Fourier analysis method is the most extensively applied signal processing tool. The Fourier transform of a signal lends itself to easy interpretation and manipulation, and leads to the concept of frequency analysis and bandwidth. Furthermore, even some biological systems, such as the human auditory system, perform some form of frequency analysis of the input signals. Both the Fourier transform and the DTFT comprise only a discrete set of frequency components (Fourier series), and the transforms diverge at those frequencies. A Fourier transform takes the time series or the continuous time and maps it to its frequency spectrum.

5. OPTIMUM EXPOSURE

Restoration is carried out for the degraded images at different exposure times. Restoration gives different quality images at those different exposure times. At one point the noise and the blur are present in the same amount and give the better image quality when restored at that exposure time. This exposure time is said to be the optimum exposure time. Images restored under this exposure time resemble the image quality closely equivalent to the original image.

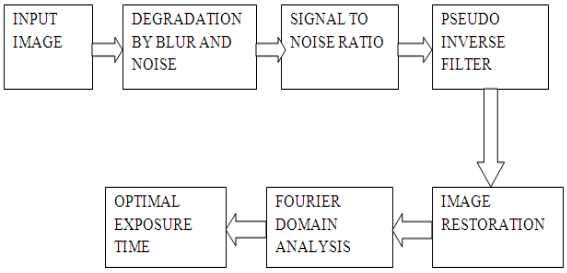

Figure.1. Block Diagram

6. EXPERIMENTAL RESULTS

In this section we show the results of the restoration performance varying with the exposure time. The performance is analyzed by considering a dataset of synthetically blurred and noisy observation. We calculate the root mean square error (RMSE) between the rescaled and the original image by the formula,

$$RMSE = 255\sqrt{\left(\frac{1}{X}\right)\sum_{x\varepsilon X}\left(\frac{1}{k\lambda}y'(x)-y(x)\right)^{2}}$$

(9)

Where , y'(x) is the rescaled image and the y(x) is the original image and X is the cardinality.

Images degraded due to uniform motion blur and poisson noise at various exposure time is shown in the figure 2. The SNR values are also shown. The sigma value shows how much noise is spread over an image i.e, the noise value. In figure 3, the restored images are shown for the same exposure time. From the result, the image with the better quality has the high SNR value and the less RMSE value.

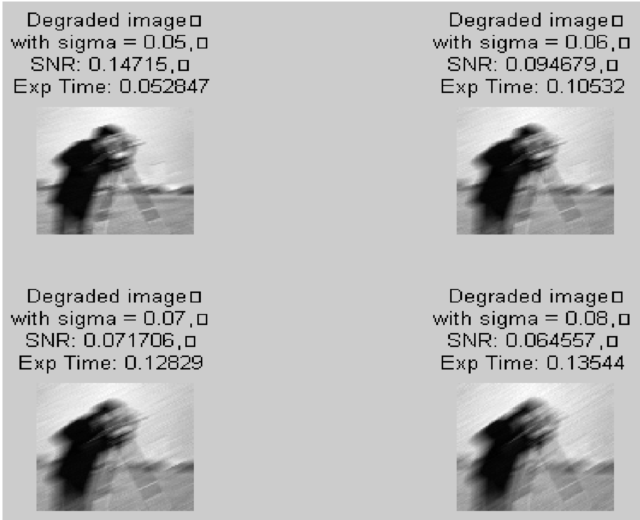

Figure.2. Images degraded due to Uniform Motion Blur and Poisson Noise at various Exposure Time

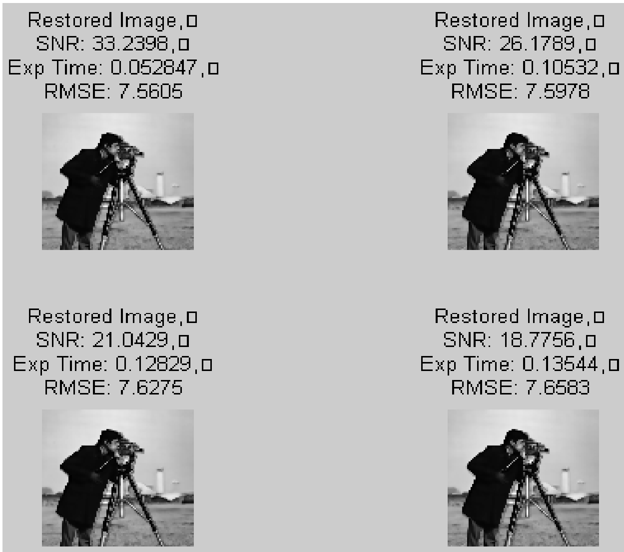

Figure.3. Restored Images at the same Exposure Time

The Matlab window shows the optimal RMSE and the optimal SNR. The result is shown below.

```
optimalRMSE =

    7.5336


optimalSNR =

   33.2398
```

Figure.4. Optimal RMSE and SNR

From the result it is evident that the first restored image is the image with better image quality and image details. Because this is the image with less RMSE value and the highest SNR value. Hence the optimal exposure time is 0.052847 seconds.

7. CONCLUSION

We have considered the images with uniform motion blur and the poisson noise under various exposure times. The SNR values were calculated and are restored using the Pseudo-inverse filters which operates pixel wise. The compensating pixels are added to the degraded image blocks to restore the image. Similarly the process is carried out and finally they are integrated to obtain the restored image. The SNR values and the RMSE values were calculated. In order to obtain the optimal exposure time the Fourier domain analysis is done. The image restored at this exposure time was better when compared to the other exposure times' restored image.

8. REFERENCES

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