Filtering image with motion blur and noise in MATLAB: A Case Study on Wiener Filter and Inverse Filter

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***Abstract*—In this case study, we first converted a color picture to grayscale image. After that, motion blur was added to the gray image. The intensity of blur was controlled by a variable and the angle was taken at random. Speckle noise was added to the blurred image. Using Inverse Filter and Wiener Filter, both motion blurred and noisy motion blurred images are restored and both of them are compared.**

Keywords—Color image, grayscale image, motion blurring, speckle noise, inverse filtering, Wiener filtering, median filtering, restoration of an image.

I. Introduction

Image restoration is a vital approach in the digital image processing world. It is used to retrieve uncorrupted, original information, as much as possible, from an image corrupted by motion blur, noise and many more [1, 2]. Image blur may occur for many reasons, one such example is motion blur[6] which is due to the slow-moving camera shutter speed comparative to the instantaneous motion of the targeted object [4], also caused by environmental effects and camera misfocus. The image also, may have various forms of noises such as Speckle noise, Salt and Pepper noise, Poisson noise, Gaussian noise, etc. The noise used in this paper is Speckle noise. Speckle noise is a multiplicative noise that affects pixels in a gray-scale image, and mainly occurs in low level luminance images such as Synthetic Aperture Radar (SAR) images and Magnetic Resonance Image (MRI) images[4]. Image restoration has many useful applications in real world, such as astronomical imaging, remote sensing, microscopy imaging, photography deblurring, and forensic science, centralized aviation assessment procedures, uniformly blurred television pictures restoration etc[4]. Often the advantages of enhancing image quality to the maximum amount possible outweigh the cost and complexity of the restoration algorithms involved. Such algorithms use techniques called Convolutional neural Network, Artificial Neural Network, and K-nearest Neighbours. To remove noise and blur of an image to restore to its original state, a technique is used, which is known as image filtering. The two most famous filters used are Wiener Filter and Inverse Filter[3].

One image restoration technique is Inverse Filter. It is restoration technique for deconvolution, i.e., when the image is blurred by a known lowpass filter, it is possible to recover the image by inverse filtering or generalized inverse filtering. The inverse filter is very sensitive to additive noise, the filter works well when the noise does not corrupt images, but in the presence of noise in the images, performance degrades significantly as high pass inverse filtration cannot eliminate noise properly because noise tends to be high frequency.

The Wiener Filter makes up for Inverse Filter, by executing an optimal trade-off between inverse filtering and noise smoothing as it is incorporated with low pass filter together with high pass filter; as a result, it works actively in the existence of additive noise within the image. It removes the additive noise and inverts the blurring simultaneously. It runs deconvolution (high-pass filter) to invert motion blurring and also compression (low-pass filter) operation to eliminate the additive noise. Also for removing motion blur and noises from images, the filter minimizes the overall mean square error (MSE) between the original image and the output image.
In this paper, the implementation of inverse filter and wiener filer are analyzed. Inverse filtering is applied into a motion blurred image of a lady at first, and then wiener filtering is also passed through the same image. After that, inverse and Wiener filtering are performed on the same motion blurred car image with Speckle (multiplicative) noise added. Finally, the comparison is made between inverse and Wiener filtering regarding their performances in restoring motion blurred images with and without Speckle (multiplicative) noise.

II. Basics of Image Restoration

Image restoration means recovering information of a corrupted image by utilizing some prior knowledge of a degradation method which has corrupted the image. Not always the reconstructed image will be the same form as the original image, rather will be an approximation of the original image. Figure 1 shows a block diagram of the image degradation and recovering steps.

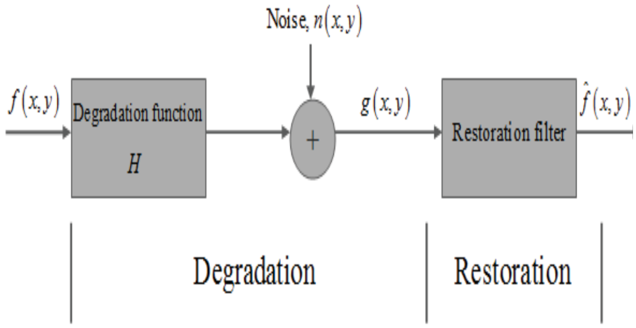

Fig. 1. Block diagram of image degradation and recovering steps

In spatial domain, the degradation of the original image can
be modeled as [25]:

$$g(x, y) = h(x, y) * f(x, y) + n(x, y) \ldots\ldots (1)$$

Where,

(x, y)= detached pixel coordinates of the image frame.

$f(x, y)$= Original image

$g(x, y)$= Degraded image

$h(x, y)$ = Image degradation function

$n(x, y)$ = Ad-on noise

III. METHODOLOGY

By using the steps shown above, simply just using Inverse Filter or Wiener Filter two experiment was carried out in this study. First one was deblurring image with motion blur with no noise and another with additive noise. The second one was carried out with multiplicative noise (Speckle noise) using the same formula and methods used for the first approach. The methods for the first approach was taken from another study and implemented with the multiplicative noise.

The results for the first approach is given below.

Figure 2 shows the deblurring of image with zero noise using Inverse Filter

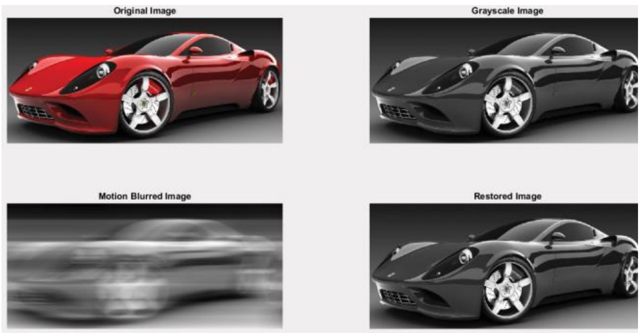

Fig. 2. Restoration of motion blurred car image with no noise by inverse filtering

Figure 3 shows the deblurring of image with additive noise using Inverse Filter.

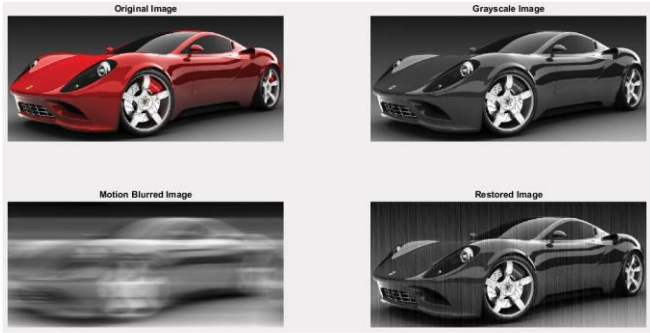

Fig. 3. Restoration of motion blurred car image with additive noise by inverse filtering

Inverse Filter was able to restore an image perfectly with no noise, but some noise is visible in the restored image when additive noise was added.

Figure 4 shows the deblurring of image with zero noise using Wiener Filter

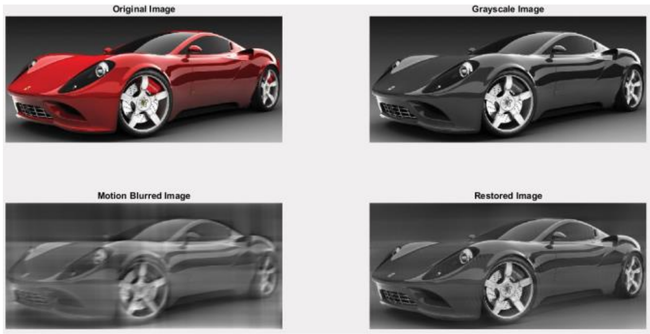

Fig. 4. Restoration of motion blurred car image with no noise by wiener filtering

Figure 5 shows the deblurring of image with additive noise using Wiener Filter

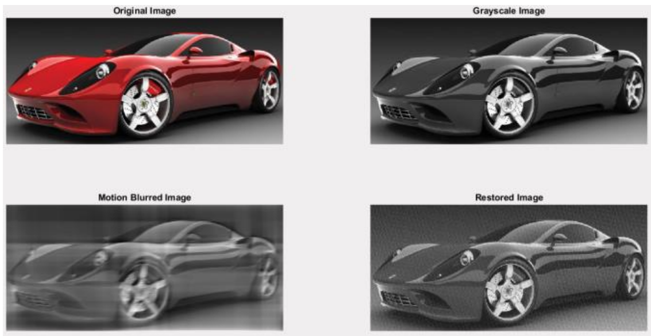

Fig. 5. Restoration of motion blurred car image with additive noise by wiener filtering

Here, wiener filter is able to remove the blur nicely but still has some noise left, just like inverse filter. But is able to remove noise more than inverse filter.

Using the second approach, the results are not quite expected. The noise was changed from additive to multiplicative. Also, the picture used is also different since the picture used in the first approach was not available to use.

A. For Inverse Filter

For inverse filter, the noise variance of speckle noise filter was set to 0.05, 3x3 median filter was used, linear motion of camera was set to 24, the angle was set to 13 for the motion blur. From the pictures below, it is noticed that the filter is not able to reconstruct the image with speckle noise added. The inverse filter is not able to correctly estimate the noise to signal ratio, also frequency of the noise is high, and we know the inverse filter is a low-pass filter, so it is not able to filter the image and as a result the finale image ends up becoming static.

Fig. 6. Image with Blur and Speckle noise

Fig. 7. Noise filtered using 3x3 Median Filter

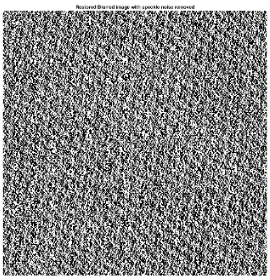

Fig. 8. Restoration of blurred image after noise filtering using Inverse Filter

Fig. 9. Inverse Filter Result

It is also noticed that in the histogram in Figure 10, the median filter is able to remove the noise, but there is nothing in the final graph, It is also noticed that in the histogram the median filter is able to remove the noise, but there is nothing in the final graph, as it was not able to get a correct estimate of noise to signal ratio.

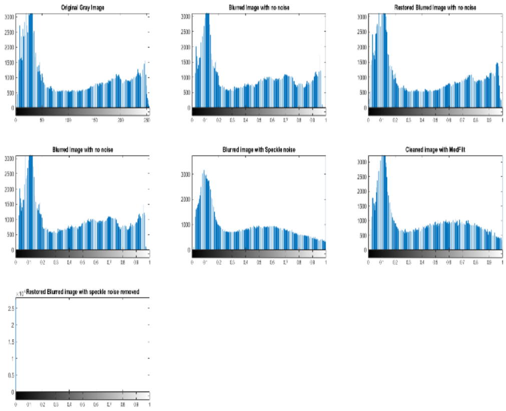

Fig. 10. Histogram of Image after Inverse Filter

B. For Wiener Filter

For wiener filter noise variance and angle were the same as for inverse filter, only the linear motion was changed to see the results. First was with 24 (same as inverse filter) and another was 30.

Since this filter has a separate parameter to calculate the noise to signal ration, it is able to filter the pictures. But this filter is not able to work properly in the presence of multiplicative noise paired with motion blurring. It is not able to completely reconstruct the image to its original form.

By changing the size of the median filter, it was able to remove almost all of the noise, then wiener filter was passed through. The filter removes very less blurring and also darkens the picture a lot. From the histogram it is visible for both pictures that the wiener filter compresses the histogram, which results in the picture to darken shown in Figure 13 and 14.

It is also noticeable in the final picture that with linear motion being 24 in Figure 11, the result becomes less sharpened compared with linear motion is 30 in Figure 12.

Fig. 11. Image after wiener filter with linear motion 24

Fig. 12. Image after wiener filter with linear motion 30

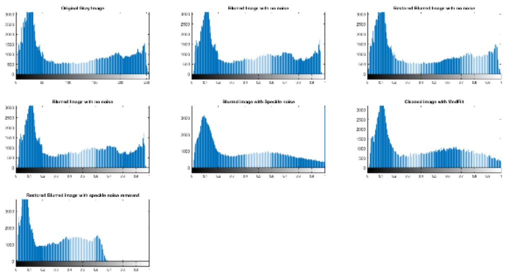

Fig. 13. Histogram with linear motion 24

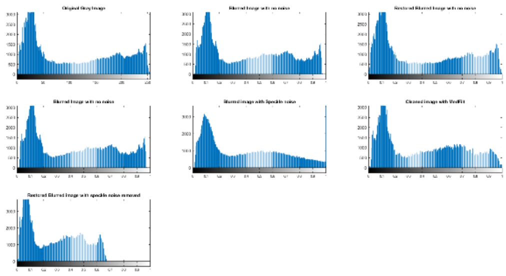

Fig. 14. Histogram with linear motion 30

IV. RESULTS AND DISCUSSION

It is observed that when the pictures are blurred and then speckle noise is added, the filters are not able to completely restore the image back to its original form after the picture was slightly cleaned with the median filter. The inverse filter failed to restore the image after the noisy image passed through the median filter, as it was not able to estimate the signal to ratio correctly, also frequency of the speckle noise is high in the image, and we know the inverse filter is a low-pass filter, so it is not able to filter the image. But when the median filtered picture passed through wiener filter, the picture was restored, but not perfectly reconstructed. As there was still noise remaining in the picture, also the motion blur was not completely removed. But the picture was understandable. Also in the histogram it is seen that the final histogram of the picture is capped to 0.68 of the colour bar for both linear motion. That resulted in the final picture being a little bit dark then the original picture.

V. CONCLUSION

The built-in filters are not suitable enough to reconstruct a motion blurred, noisy image back to the original one. The filters have to be modified to be able to identify the noises even better. The low pass filter in the built-in function can be improved even further to clean the image properly.

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