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Image Restoration Model using Total Variance, Bilateral and Wavelet Denoising Filter

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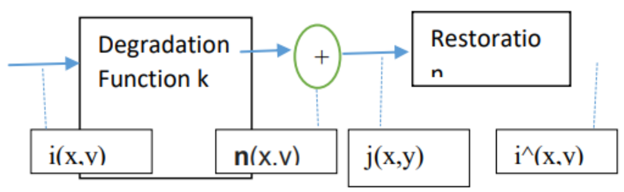
Abstract: Noise in images are most common due to various degradation. Noises in images are random variations in images due to lighting conditions, camera electronics, surface reflectance, lens, atmospheric conditions and motions (Either camera is moving or object is moving). Image Restoration is a process which restores a degraded image into its original image which has been degraded by some degradation model which degraded the image. Images are degraded due to various reasons. The first and foremost reason for image degradation is the fault in the imaging devices during the image acquisition process. The noise is generated in the imaging devices and is propagated to the image. The second source of degradation in image is the noise added during the image transmission. This type of image degradation is most common. The third source of image degradation is due to the motion blur and atmospheric turbulence. This paper analyzes various image noise models and restoration techniques. Particularly in analyses three kind of filters namely total variance filter, bilateral filter and wavelet image denoising. The image restoration is measured using the PSNR and SSI of original and degraded images

Index Terms: Image Degradation, MSE and SSI, Total Variation Filter, Bilateral Filter, Wavelet denoising, PSF

I. INTRODUCTION

Noise in image can be reduced using the image enhancement techniques such low pass filters or smoothing mask, but it is not image restoration. Any image restoration model must have a definition of goodness of measure [1]. A priori knowledge of image degradation model must be known.



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Here i(x,y) is the two dimensional input image which is tainted due to function K and the output of the degradation function is merged with the noise **η**(x,y) and the resulting image is output j(x,y). So j(x,y) is the contaminated image which we want to recover using image restoration techniques using the priori knowledge of the degradation model with goodness of measure. The restored image i^(x,y) is the estimate of the original image because in most of the cases , it is very difficult to get back the old image. The degraded image j(x,y) is represented as the mathematical equation[5]

$$j(x,y) = K(i(x,y) * i^{\wedge}(x,y) + \eta\,(x,y)$$

II. ESTIMATION OF IMAGE DEGRADATION

There are certain cases where image restoration is necessary. The first case is the fault in the imaging devices during the image acquisition process such as camera is not properly focused . The noise is generated in the imaging devices and is propagated to the image. The second source of degradation in image is the noise added during the image transmission. This type of image degradation is most common. The third source of image degradation is due to the motion blur and atmospheric turbulence. There are three different techniques for estimation of the image degradation model. The first technique is simply by observation and second technique is by means through experimentation and third technique is by using mathematical modelling techniques.

The first technique of estimating the degradation using observation is done by identifying a small region which contains some simple structure and getting the approximated reconstructed image say i_s^(x,y) for the given j_s^(x,y). Let I_s(n,m) and J_s(n,m) be the Fourier transformation of the i_s^(x,y) and j_s^(x,y). The degradation function K_s(n,m) is given by the equation $Ks(n,m) = \frac{Js\,(n,m)}{Is\,(n,m)}$. Here the noise term is neglected for simplicity and η=0.[2]

The next technique for estimation of degradation function is by experimentation. Here the purpose is to find the PSF or impulse response of the imaging setup which fully characterizes the imaging system. So if the impulse response is already well-known, then the output of the system to any random input can be calculated from the impulse response.

III. CONSTRAINED LEAST SQUARE FILTERING

The characteristics of the wiener filter lies upon the correct approximation of the value k which represents power spectrum of the original un-degraded image.

But constrained least square filtering does not make any assumption the original un-degraded image, but it uses the noise probability distribution function . The mean and variance of the noise are m_η and $\sigma\eta^2$.
The matrix representation of function g is given by j=Ki+ η, the 2nd derivative or laplacian operator is used to enhance the anomalies or discontinuity in the image.
So the minimization of laplacian of reconstructed image will ensure that the reconstructed image will be smooth.
The optimal criteria is given by $C = \sum \quad \sum \nabla 2\, i(x, y)$ where $\nabla 2\, i(x, y)$ is the laplacian operation. So this approach is to minimize this criteria subject to the constraints that $||j - Ki^{\wedge}||2$ =|| η ||2 where i^ is the reconstructed image. Because of this constraint , this method is called as constrained least square filter. The frequency domain solution is given by [3]

$I^{\wedge n,m} = [\frac{K*(n,m)}{K(n,m)^{\wedge}2}$ + ɤ P(n,m)^2] J(n,m)

Where P(x,y) is the laplacian mask $\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$ and P(n,m) is the Fourier transform of the laplacian mask. ɤ is iteratively adjusted to give the optimal value.

Different restoration methods for noise removal are Mean, Order Statistics and Adaptive Filters. Arithmetic mean filter is most common for noise elimination in the images. This filter calculates the intensity of each resulting image pixel by calculating arithmetic mean of the surrounding adjacent pixels of the equivalent input pixel. Geometric and Harmonic mean filter is based on the geometric and Harmonic mean of the surrounding adjacent pixels equivalent to the input pixel. Order statistics filters is based on the statistical analysis [4]

IV. TYPES OF FILTERS

Image Filtering methods are divided into linear filters and nonlinear filters. Inverse filtering, wiener filtering and constrained least square are examples of linear restoration methods. Linear filters are simple with modest computation. But nonlinear filters are that their behavior is not predictable and also it requires considerable computation.. Convolutional filters are based upon the convolution operation. It consider a square array of pixels for convolution operation. Each pixel value in the square mask is substituted by the mean of the gray levels over a square mask centered on that pixel. Square mask sizes are typically in the order of 3*3, 5*5, or 9*9 matrix of pixels but other order of matrices are also acceptable. This square mask is called a window or kernel, since in the computer manipulation of a matrix can be imagined as moving kernel systematically from one pixel to the next. Another set of filters called averaging filters are used in the decrease of inappropriate details present in the image. Another example of nonlinear filter is median filter or order-statistics filter. These filters are used to reduce the noise present in the image. This paper compares particularly three kind of filters namely total variance filter, bilateral filter and wavelet image denoising filter. We

Total Variance Filter

Total Variance Filters are based on the principle that noise introduces variance into the input images and signals with noise have high total variation.This filter try to reduce the total variation of the input image so that the resulting image is closest to the original image

Bilateral Filter

Bilateral Filter is an another filter used to denoise the image. This works better with preserving the edges in the input images than any other filters. It works on the differences in color intensity and depth distance between the different portions of the input image.

Wavelet Denoising Filter

This filter first transform the input image into wavelet transform. This wavelet transform localizes the image features existing in the input image to diverse scales and it localizes noise present in the input image into typically smaller scales. It concentrates image features into a few large magnitude co-efficient and thus preserves the image quality.

V. IMPLEMENTATION

To Compare the result of the various image restoration filters, here we have taken into account the MSE and SSIM of original , degraded and restored images. Two cases for filtering is taken into account. For Case 1 , Total variance filtering weight factor is 0.1, bilateral filter sigma color is 0.05, wavelet denoising ycbcr=True, and for case 2 Total variance filtering weight factor is 0.2, bilateral filter sigma color is 0.1, wavelet denoising ycbcr=False . It shows that MSE and SSIM of original image compared with itself is zero and one which means that mean squared error is null and total structural similarity. But When original image is compared with noisy and noisy constant image, MSE is 192 and SSIM is more for noisy constant image. The following figures [Fig 1,2 3 &4] shows the MSE and SSIM of original, noisy and noisy constant images. Followed by adding random noise of various magnitudes and comparison of the MSE and SSIM [Fig v&vi] of reconstructed image using the total variance filter, bilateral filter and wavelet image denoising filter. In Fig v & vi, the MSE and SSIM of total variance filter , bilateral filter and wavelet image denoising filters are compared. It shows that total variance filter is better for both the cases , but wavelet image denoising filter preserves the image quality.

Fig i: Original Rose Image

Table 1: Comparison of MSE and SSIM of Original, Noisy and Noisy Constant Image

	Type of Image	MSE	SSIM
1	Original	0.00	1.00
2	Noisy	192.00	0.08
3	Noisy Constant	192.00	0.81

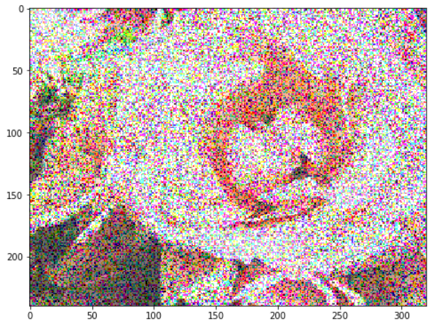

Fig ii: Noisy Rose Image

Fig iii: Noisy Constant Image

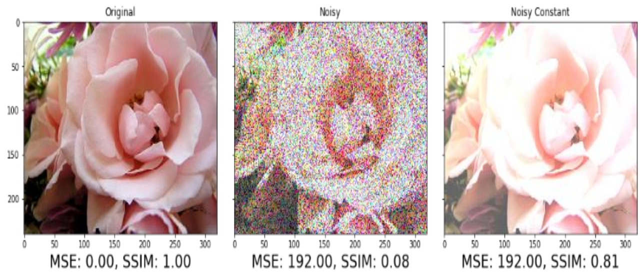

Fig iv: (a) Fig: iv (b) Fig iv (c)

Fig: iv (a)MSE&SSIM of Original Image , iv(b) MSE&SSIM of Noisy Image, iv(c) MSE&SSIM of Noisy Constant Image

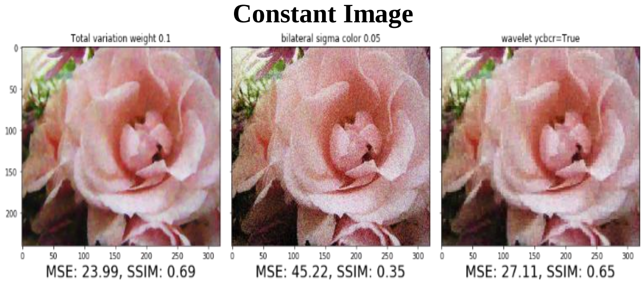

Fig v: (a) Fig: v (b) Fig v(c)

Fig: v (a)MSE&SSIM of Total variance Filter (case 1),v(b) MSE&SSIM of Bilateral Filter (case 1), v(c) MSE&SSIM of Wavelet denoising filter (case 1)

Fig vi: (a) Fig: vi (b) Fig vi(c)

Fig: vi(a)MSE&SSIM of Total variance Filter (case 2),vi(b) MSE&SSIM of Bilateral Filter (case 2), vi(c) MSE&SSIM of Wavelet denoising filter (case 2)

Table 2: Comparison of MSE and SSIM of Total Variance Filter, Bilateral Filter and Wavelet Denoising Filter Case 1

	Type of Filter	MSE	SSIM
1	Total Variance Filter (denoising 1)	23.99	0.69
2	Bilateral Filter (denoising 1)	45.22	0.35
3	Wavelet Image Denoising Filter (denoising 1)	27.11	0.65

Table 3: Comparison of MSE and SSIM of Total Variance Filter, Bilateral Filter and Wavelet Denoising Filter Case 2

	Type of Filter	MSE	SSIM
1	Total Variance Filter (denoising 2)	24.12	0.76
2	Bilateral Filter (denoising 2)	36.11	0.51
3	Wavelet Image Denoising Filter (denoising 2)	28.79	0.63

VI. CONCLUSION

After analyzing various image noise models and restoration techniques proposed by different researchers, the result shows that wavelet image denoising preserve the image quality. The result in Table 1 shows that even MSE measure is same for noisy and noisy constant image, but its structural similarity index value is different for the images. The result in Table 2 and Table 3 compares the MSE and SSIM of denoised image using the total variance filter, bilateral filter and wavelet image denoising filter for two cases and it shows that the total variance filter is better than the other filters, but wavelet image denoising preserve the image quality.

For further enhancement, machine learning techniques can be employed for restoration.

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