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RESTORATION OF REAL NOISY IMAGE USING DENOISING AND ENHANCING TECHNIQUES

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ABSTRACT

Noise always disturbs image quality. Many filters can be used for denoising purpose but adds blurry effects. The need of removing degradation and preserving image details is become interesting research area in Image Processing. This paper presents a method for image restoration. The proposed method is based on three major techniques, Phase preserving approach, Normalization technique and Wavelets Transformation (WT). This study focuses to restore an image that has an additive white Gaussian noise and the proposed method is trying to restore it approximately to look like the original. The results obtained in MATLAB shows the denoising technique minimises noise present in the image and Wavelet Transform restore the image to a certain extent.

KEYWORDS: Image degradation process, Image restoration, process, Phase Preserving algorithm, Normalization Technique, Wavelet Transformation.

INTRODUCTION

Image Restoration is an objective process which models the degradation and then applies inverse operation to get approximation of the original image. Image Restoration can be done in Spatial Domain and Frequency Domain [1]. Filtering techniques can be used to show certain image characteristics:

- Improve contrast(Enhancement)
- Remove noise(Smoothing)
- Template Matching
- Sharpening

The linear filtering techniques are very simple in implementation but they add blurring effect in denoised image. Also some non-linear filtering techniques can be used to remove AWGN [2,3,4,5].The work in this paper is based on three techniques:1) Denoising 2) Normalization technique and 3) Wavelet Transform. Phase Preserving Algorithm is used for denoising the image while preserving the phase information. Normalization technique is used for enhancing the intensity values of the image. And Wavelet transformation is used for removing degradation.

This paper is organized as follows. Section II describes image restoration process in Spatial Domain and Frequency Domain. The model represents degradation/restoration process model. Proposed model based on Phase Preserving algorithm, normalization technique and WT for Image Restoration is given in Section III. Section IV presents experimental results showing results of images restoration. Finally, conclusion is presented.

IMAGE DEGRADATION AND RESTORATION PROCESS

Restoration tries to recover a degraded image. Degradation occurs due to noise or blur. The Spatial Domain Filtering Techniques are used to recover an image that has degradation due to noise only. If the degradation causes due to blur then Frequency Domain Filtering Techniques are used. It is also applicable for the combination of blur and noise.

- Source of blurring is Point-Spread Function (PSF)
- Sources of noise: Image acquisition, environmental conditions, Quality of sensors, Image transmission, Human Interferences.

Various types of noise are Additive noise (Additive White Gaussian Noise),Multiplicative noise (Speckle noise), subtractive noise (impulse noise).Linear Motion blur, atmospheric blur, out-of-focus blur etc. are some types of blur. Depending upon noise type or blur type, filtering technique is used in Spatial and Frequency Domain.

However, this model concerns with suppression of Additive White Gaussian Noise (AWGN). Additive

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noise means a random value is added at each pixel and White noise means the value at a point is independent on the value at any other point. The noise term represented by Gaussian Probability Density Function (PDF).The probability Density Function given by,

$$F\,(g) = \frac{1}{\sqrt{2\pi\sigma}}\; e^{\frac{-(g-m)^2}{2\sigma^2}} \qquad (1)$$

where g represents the gray level, m is the mean or average of the function, and σ is the standard deviation of the noise. Gaussian noise is additive in nature i.e. the Gaussian distributed noise values gets added to the intensity values of the image.

Degradation Process

Two types of degradations are noise and blur. Fig. 1 shows the degradation process model. When degradation causes due to noise then degraded image can be modelled in:

1) Spatial Domain:

$$g(x1,\, x2) = f(x1,\, x2) + \eta(x1,\, x2) \qquad (2)$$

where g is the degraded image, f is the original image and η is the additive noise.

2) Frequency Domain:

$$G(x1,\, x2) = F(x1,\, x2) + N(x1,\, x2) \qquad (3)$$

The capital letters are the Fourier Transforms of the corresponding small letters in equation (2).

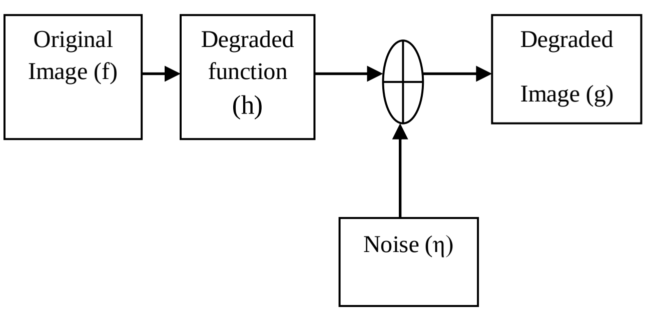

Fig.1 Degradation Process Model

In Linear, position invariant process:

1) Spatial Domain: The degraded image can be modelled as the convolution of the degradation (point spread) function with an image followed by the addition of noise such as:

$$g(x1,\, x2) = h(x1,\, x2) * f(x1,\, x2) + \eta(x1,\, x2) \qquad (4)$$

where h is the spatial representation of the degradation function and the symbol " * " indicates convolution operator.

h(x1, x2): Point Spread Function(PSF) that operate on a point of light to obtain degradation. The PSF gets convolved with the original image to give the degraded image.

2) Frequency Domain: The degraded image can be modelled as the product of the transforms of the image and degradation, followed by the addition of the transform of the noise

$$G(u1,\, v1) = H(u1,\, v1)F(u1,\, v1) + N(u1,\, v1) \qquad (5)$$

where G, H, F, and N are the Fourier transforms of g, h, f, and η, respectively

H(u1, v1): Optical Transfer Function (OTF)

Restoration Process Model

One can obtain an estimate *f*^ of the original image *f* with having some knowledge about the degradation.

Fig. 2 Restoration Process Model

Estimation of Degradation Function

The degradation can be estimated by one of the following techniques:

• Estimation by image observation.
• Estimation by experimentation
• Estimation by modelling

Inverse Filtering[1]

The simplest approach to restoration is inverse filtering. Once H(u1,v1) has been estimated, an estimate Fˆ(u1,v1) can be computed simply by dividing the transforms:

$$\hat{F}(u1, v1) = \frac{G(u1, v1)}{H(u1, v1)} \quad or$$

$$\hat{F}(u1, v1) = F(u1, v1)\ \frac{N(u1, v1)}{H(u1, v1)} \qquad (6)$$

PROPOSED METHOD

The Proposed method is based on three major techniques:

1. Denoising using Phase Preserving Algorithm
2. Normalization Technique
3. Wavelet Transformation to reduce degradation

The main idea is to show that by combining above mentioned techniques together, the degraded real images would be restored. Fig. 3 illustrates the proposed method's restoration process diagram.

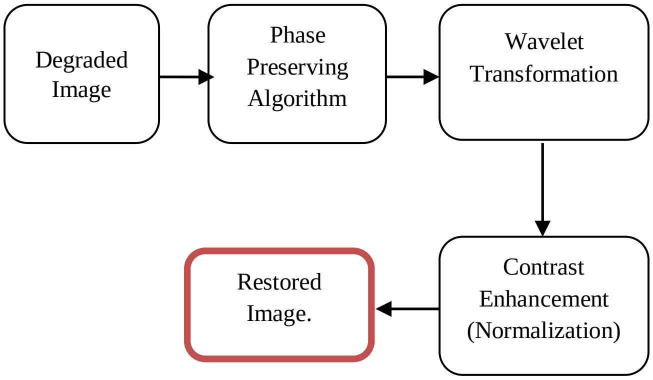

Fig. 3. Restoration Process Diagram

Denoising using Phase Preserving Algorithm[6]

Image denoising refers to the recovery of digital images that have been contaminated by Additive white Gaussian noise. The phase preserving algorithm presented states that each pixel value in the frequency domain has a real part which represents the phase and an imaginary part which represents the amplitude. The main idea of this algorithm is to keep the phase unchanged and change the amplitude by shrinking.

This algorithm works by extracting the local amplitude of the image using log Gabor function and also extracts local phase of the image using Gaussian spread function.

The log Gabor equation is:

$$G(f)=\exp[(-(\log(f/f_0))^2) / (2(\log(\sigma/f_0))^2)] \quad (7)$$

Where f is the radial component, (σ/f_0) is pre-calculated value and f_0 is calculate as

$$f_0= [(\frac{1}{wavelength}) / 0.5] \quad (8)$$

The Gaussian spreading function equation is:

$$\Psi(r) = (\pi b^2)^{-1}\exp(-r^2/b^2) \quad (9)$$

The wavelength is initially set to 2.

The Gaussian spreading function and log Gabor function is now convolved to form a filter. Before convolving filter with the image, a Fourier shifting operation is applied to shift all zero values to the corners and the high and low values to the centre. By now the overall filter is done and ready to be convolved with the noisy image. Then, the filter is convolved with the image which has been transformed to the frequency domain. There will be a 90 degree phase difference between the real numbers and the imaginary numbers of the same image. By taking the inverse Fourier Transform of the result after the convolution of the image with the created filter, even-symmetric element will be in the real part of the result, and the odd-symmetric elements will be in the imaginary part of the result. Fig 4 shows, the amplitude is the length of the vector, and the phase is the angle of the vector.

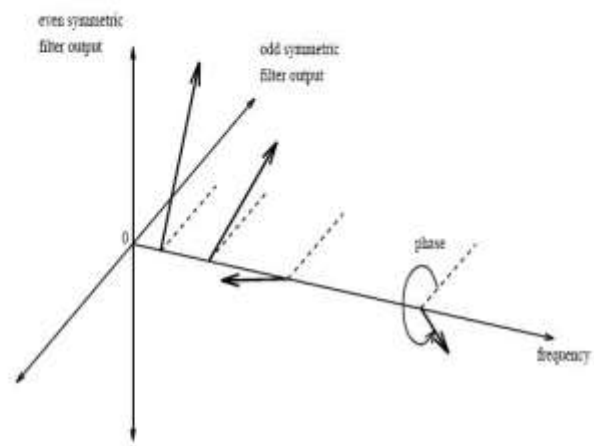

Fig. 4 Phase and amplitude of the Response vector at different scale [7]

1) *Soft Thresholding:* The choice of a threshold is an important point. It plays a major role in the removal of noise in images because denoising most frequently produces smoothed images, reducing the sharpness of the image. There are two types such as hard- thresholding and soft-thresholding types.

In hard thresholding, all coefficients whose magnitude is greater than the selected threshold value remain as they are and the others with magnitudes smaller than selected threshold value are set to zero. It creates a region around zero where the coefficients are considered negligible. Soft thresholding shrinks coefficients above the threshold in absolute value. Phase preserving algorithm uses automatic thresholding instead of manual thresholding. The threshold equation is [7]:

$$T= \mu_r+ k\sigma_r \quad (10)$$

Where μ_r is the mean of the Rayleigh distribution and σ_r the variance of the Rayleigh distribution.

In practice, it can be seen that the soft method is much better and yields more visually pleasant images. This is because the hard method is discontinuous and yields abrupt artifacts in the recovered images. Also, the soft method yields a

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smaller minimum mean squared error compared to hard form of thresholding.

Normalization Technique [6]

Normalization is the technique that would give the image a typical gray level intensity, so if the image is too dark, it would be less dark and if the image is too white, it would be less white. The following equation illustrates Normalization operation:

$$N_{ij} = \frac{A_{ij} - \min}{\max - min} * 255 \qquad (11)$$

Where (Nij) is the normalized value, (Aij) is the current pixel value, min is the minimum pixel value in the image and max is the maximum pixel value in the image.

Wavelet Transformation

The wavelet based approach finds applications in denoising images corrupted with Gaussian noise. Wavelet transform has been a powerful and widely used tool in image denoising because of its energy compaction and multiresolution properties .In WT, Discrete Wavelet Transformation (DWT) provides most compact representation. DWT is applied to the image for separation of horizontal, vertical and diagonal details of the image.

To restore the original image using Wavelet Transformation, initially [8]:

1) Estimate Point Spread Function (PSF) of the degrade image.
2) Then we find Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) of the resultant image.

Algorithm

1) Collect Real image database.
2) Add additive white Gaussian noise with variable density.
3) Calculate the standard deviation of the angular Gaussian function used to construct filters in the freq. plane.
4) Compute 2 D Fourier transform of the noisy image.
5) Obtain normalized radius from centre and angle.
6) For each orientation of the filter calculate angular filter component.
7) For each scale, construct the filter and convolve the image with this filter designed.
8) Estimate the mean and variance in the amplitude response of the smallest scale filter pair at this orientation.
9) Apply soft thresholding.
10) Restore the original image using Wavelet Transformation.
    a. Initially the PSF is estimated of the sampled degraded image.
    b. Impose Fourier constraint 1.
    c. Apply FFT.
    d. Apply Fourier constraint 2.
    e. Find IFFT of the resultant.
11) Apply normalization technique for image enhancement.
12) Compute performance parameter like PSNR or MSE to validate the performance of the proposed algorithm.

RESULTS

Image Metrics

As Image Restoration is an objective process, the objective evaluation of an image is performed by calculating error and error related parameter mathematically. The commonly used image metrics are Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Peak Signal to Noise Ratio (PSNR) etc.

As original image, noisy image and denoised image are represented by f(x1, x2), g(x1,x2) and f^(x1, x2) respectively. Let the image be of the size M × N i.e i= 1, 2,…., M and j=1,2,…,N.

The MSE is defined as:

$$\text{MSE}= \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(\text{f}^{\hat{}}(\text{i,j})-\text{f(i,j)})^2}{M \times N} \qquad (12)$$

PSNR is expressed in dB. It is a ratio of peak signal power to noise power. It is defined as[9]:

$$\text{PSNR}= 10.\log_{10} \left(\frac{\text{R}^2}{\text{MSE}}\right) \text{dB} \qquad (13)$$

R is the maximum fluctuation in the input image data type. If the input image has a double-precision floating-point data type, then *R* is 1. If it has an 8-bit unsigned integer data type, *R* is 255.

Experimental Results

A)

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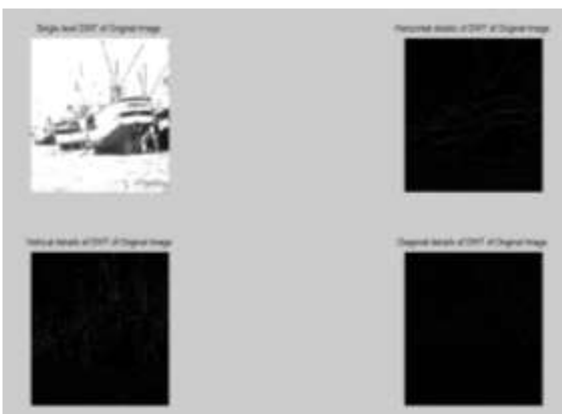
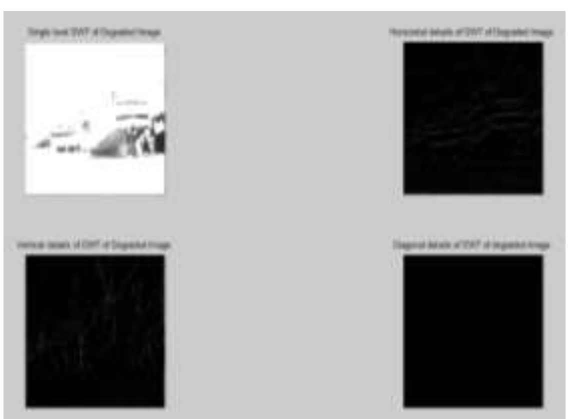
B)

C)



D)



E)

F)

Fig. 5 Results of Proposed Method A) Original image B) Degraded image C) Denoised image using Phase Preserving Algorithm D) DWT of original image showing single ,horizontal, vertical and diagonal details E) DWT of degraded image showing single ,horizontal, vertical and diagonal details F) restored image

Performance of the proposed method on different images based on PSNR and MSE values are shown as follows:

Table 1 Result of psnr and mse for restored images using proposed method

Image Name	Degraded Image	PSNR in dB	MSE
Boat	5.26	18.87	842.94
Lena	5.61	19.69	697.87
bridge	5.95	16.13	1.5823e+003
couple	5.83	14.76	2.1692e+003

CONCLUSION

Many filters can be used for restoration purpose, but it faces problem of adding blurry effects in output image. With the proposed method denoising is carried by Phase Preserving Algorithm which also preserves the phase information of the image and Wavelet transforms helps to give compact representation of the image and Normalization enhances the image by normalizing intensity values. With the experimental results, it can be shown that the proposed method works good for restoration purpose.

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