COMPARATIVE ANALYSIS OF DWT, WEINER FILTER AND ADAPTIVE HISTOGRAM EQUALIZATION FOR IMAGE DENOISING AND ENHANCEMENT

Rajwant Kaur
Student Masters of Technology
Department of CSE
Sri Guru Granth Sahib World University
Fatehgarh Sahib, Punjab, India

Sukhpreet Kaur
Assistant Professor
Computer Science and Engineering
Sri Guru Granth Sahib World University
Fatehgarh Sahib, Punjab, India

ABSTRACT- This paper presents image denoising and Gaussian noise reduction model using different techniques including discrete wavelet transform, adaptive histogram equalization and weiner filter. Wavelets are the latest research area in the field of image processing and enhancement. The results show a comparison of three mentioned techniques showing an improved visual quality in wavelet transform technique than other two older techniques and is effective for removing the Gaussian noise corrupted image alone. Wavelet analysis represents the next logical step: a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. Generally biomedical image is corrupted by Gaussian noise. So image de-noising has become a very essential exercise all through the diagnose. 2-D Discrete wavelet transform have been studied and an algorithm is developed to perform image denoising for Gaussian noise corrupted images using discrete wavelet transform. Results have been obtained using PSNR and MSE for three techniques. Processing time for different techniques implementation on MATLAB has also been framed. Gaussian noise reduction is another main criterion for determining the image quality objectively.

KEYWORDS: Discrete Wavelet Transform, Image Denoising and enhancement, Gaussian Noise

1. INTRODUCTION

The basic measure for the performance of an enhancement algorithm is PSNR, defined as a peak signal to noise ratio. Quality and compression can also vary according to input image characteristics and content. In wireless transmission and remote sensing applications the basic problem that is induced in images is the introduced Gaussian noise. Gaussian noise becomes a dominating factor in degrading the image visual quality and perception in many other images. There could be noises due to loss of proper contact or air gap between the transducer probe and body; there could be noise introduced during the beam forming process and also during the signal processing stage. Gaussian noise is a multiplicative noise, i.e. it is in directly proportional to the local grey level in any area. The signal and the noise are statistically independent of each other. Removal of noise from an image is the one of the important tasks in image processing. Depending on nature of the noise, such as additive or multiplicative noise, there are several approaches for removal of noise from an image. Image Enhancement improves the quality (clarity) of images for human viewing. Removing blurring and noise, increasing contrast, and revealing details are examples of enhancement operations. Image Processing basically includes analysis, manipulations, storage and display of graphical images from sources such as photographs, drawings and so on. Image processing spans a sequence of 3 phases, which are the image acquire, processing and display phase. The image acquires phase converts the differences in colouring and shading in the picture into binary values that a computer can process. The enhancement phase can include image enhancement and data compression. The last phase consists of display or printing of the processed image. The main objective of Image denoising techniques is necessary to remove such noises while retaining as much as possible the important signal features. Histogram equalization is that the global properties of the image cannot be properly applied in a local context, frequently producing a poor performance in detail preservation. In a method to enhance contrast is proposed; the methodology consists in solving an optimization problem that maximizes the average local contrast of an image. Weiner filter was adopted for filtering in the spectral domain. Wiener filter (a type of linear filter) is applied to an image adaptively, tailoring itself to the local image variance. Where the variance is large, Wiener filter performs little smoothing. Where the variance is small, Wiener performs more smoothing. This approach often produces better results than linear filtering.

2. LITERATURE REVIEW

There are many research papers that propose Histogram modelling techniques to modify an image so that its histogram has a desired shape. This is useful in stretching the low-contrast levels of an image with a narrow histogram, thereby achieving contrast enhancement. This is driven by the lack of removal of non-uniform illumination, as a result of which presence of extra light pixels at some positions in the image and extra dark pixels around other particles in the image is variable, so this contrast enhancement at the starting of the image processing does not create the accurate...
boundaries of the objects to be detected. On the other hand, uneven background, also known as background bias, background intensity in-homogeneity, or non-uniform background, is the problem that an ideal image \( f \) is corrupted by an uneven background signal \( b \) so that the observed image \( I = f + b \). Recovering \( f \) from \( I \) is not an easy task when \( b \) is non-uniform. In essence, both the varying illumination and the uneven background are inhomogeneous intensity patterns that are either multiplicative or additive. [8] Komal Vij, et al. has proposed image enhancement method to increase image visibility and details. They covers all the factors like enhancement efficiency, computational requirements, noise amplification, user intervention, and application suitability. [10] Yan Wan, et al. has proposed a dual threshold calculating method to obtain accurate and continuous fiber edge, as well as to control the image noise. [11] M. Kowalczyk, et al. has proposed conception of effectively working groups of morphology functions in particular image cases. A common issue irrespective of the type of camera and method of microscope attachment is uneven illumination at the edges of the image, otherwise known as vignetting. This may be attributed to multiple factors from the illumination filament, the design of the light path between the camera and the microscope, or the behavior of the imaging device. Conventional digital cameras—for example, are not designed for microscopy imaging, and many of their automatic functions can interfere with the correct aperture and exposure settings. [12] David Menotti has proposed two methodologies for fast image contrast enhancement based on histogram equalization (HE), one for gray-level images, and other for color images. For gray-level images, technique called Multi-HE has been proposed. [13] Ley, et al. has proposed a simple background illumination correction based approach for improving matting problems with uneven or poor lit blue-green screens. [14] Joanna Sekulska, et al. has proposed general methods of biological images processing. These techniques are oriented to better image interpretation. [7] has proposed an automatic method for estimating the illumination field using only image intensity gradients. [15] has proposed a novel model-based correction method is proposed, based on the assumption that an image corrupted by intensity inhomogeneity contains more information than the corresponding uncorrupted image. [9] has proposed a new approach to the correction of intensity inhomogeneities in magnetic resonance imaging (MRI) that significantly improves intensity-based tissue segmentation.

3. PROBLEM FORMULATION

To design an image denoising and Gaussian noise reduction model using different techniques including discrete wavelet transform, adaptive histogram equalization and weiner filter.

Wavelets are the latest research area in the field of image processing and enhancement. The results show a comparison of three mentioned techniques showing an improved visual quality in wavelet transform technique than other two older techniques and is effective for removing the Gaussian noise corrupted image alone.

4. RESEARCH METHODOLOGY

4.1 Discrete Wavelet Transform

Wavelet analysis represents the next logical step: a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information.

![Wavelet Transform](image)

Figure 1: Wavelet Transform on a signal Wavelet Transform in contrast with the time-based, frequency based, and STFT views of a signal:

![Comparison of Various Transform Techniques](image)

Figure 2: Comparison of Various Transform Techniques

The discrete wavelet transform (DWT) refers to wavelet transforms for which the wavelets are discretely sampled. A transform which localizes a function both in space and scaling and has some desirable properties compared to the Fourier transform. The transform is based on a wavelet matrix, which can be computed more quickly than the analogous Fourier matrix. Most notably, the discrete wavelet transform is used for signal coding, where the properties of the transform are exploited to represent a discrete signal in a more redundant form, often as a preconditioning for data compression.
**Biorthogonal Wavelet**

This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets, one for decomposition (on the left side) and the other for reconstruction (on the right side) instead of the same single one, interesting properties are derived.

![Bior1.5 Wavelet Function Waveform](image)

**Figure 3**: Bior1.5 Wavelet Function Waveform

### 4.2 Adaptive Histogram Equalization

Histogram of an image represents the relative frequency of occurrence of grey levels within an image. Histogram modelling techniques modify an image so that its histogram has a desired shape. Histogram equalization is used to enhance the contrast of the image such that it spreads the intensity values over full range. Under Contrast adjustment using histogram equalization, overall lightness or darkness of the image is changed, i.e. in this technique, pixel values below specified values are mapped to black and pixel values above a specified value are mapped to white. The result is linear mapping of a subset of pixel values to entire range of display intensities. So, histogram equalization technique basically compares every pixel in the input image with a predefined pixel value that sets all the pixel values above the threshold value to be 1 i.e. white in color and others below this value to be 0, or black. Histogram equalization is applicable to the gray scale images where the main target is to enhance the image in order to see the details in the image clearly for future processing and this is achieved by increasing the dynamic range of the entire histogram.

### 4.3 Weiner Filter

Weiner filter was adopted for filtering in the spectral domain. Weiner filter (a type of linear filter) is applied to an image adaptively, tailoring itself to the local image variance. Where the variance is large, Weiner filter performs little smoothing. Where the variance is small, Weiner performs more smoothing. This approach often produces better results than linear filtering. The adaptive filter is more selective than a comparable linear filter, preserving edges and other high-frequency parts of an image. However, wiener filter require more computation time than linear filtering. The inverse filtering is a restoration technique for deconvolution, i.e., when the image is blurred by a known low pass filter, it is possible to recover the image by inverse filtering or generalized inverse filtering. However, inverse filtering is very sensitive to additive noise. The approach of reducing one degradation at a time allows us to develop a restoration algorithm for each type of degradation and simply combine them. The Wiener filtering executes an optimal tradeoff between inverse filtering and noise smoothing. It removes the additive noise and inverts the blurring simultaneously. The Weiner filtering is optimal in terms of the mean square error. In other words, it minimizes the overall mean square error in the process of inverse filtering and noise smoothing. The Wiener filtering is a linear estimation of the original image. The approach is based on a stochastic framework. The orthogonality principle implies that the Wiener filter in Fourier domain can be expressed as follows:

\[
W(f_1, f_2) = \frac{H^*(f_1, f_2)S_{xx}(f_1, f_2)}{\|H(f_1, f_2)\|^2 S_{xx}(f_1, f_2) + S_{nn}(f_1, f_2)}
\]

where \(S_{xx}(f_1, f_2), S_{nn}(f_1, f_2)\) are respectively power spectra of the original image and the additive noise, and \(H(f_1, f_2)\) is the blurring filter. It is easy to see that the Wiener filter has two separate part, an inverse filtering part and a noise smoothing part. It not only performs the deconvolution by inverse filtering (high pass filtering) but also removes the noise with a compression operation (low pass filtering).

### 5. GAUSSIAN NOISE MODEL

Mathematically the image noise can be represented with the help of these equations below:

\[
V(x, y) = g[u(x, y)] + \eta(x, y) \tag{1}
\]

\[
g[u(x,y)] = \iint h(x, y; x', y')u(x', y')dx'dy' \tag{2}
\]

\[
D(x, y) = \int [g(u(x, y))]\eta_1(x, y) + \eta_2(x, y) \tag{3}
\]

Here \(u(x, y)\) represents the objects (means the original image) and \(V(x, y)\) is the observed image. Here \(h(x, y; x', y')\) represents the impulse response of the image acquiring process. The term \(\eta(x, y)\) represents the additive noise which has an image dependent random components \(f[g(w)]\) \(\eta_1\) and an image independent random component \(\eta_2\). Gaussian noise can be modeled as

\[
V(x, y) = u(x, y) s(x, y) + \eta(x, y) \tag{4}
\]

Where the speckle noise intensity is given by \(s(x, y)\) and \(\eta(x, y)\) is a white Gaussian noise [1]-[3]. The main objective
of image-de-noising techniques is to remove such noises while retaining as much as possible the important signal features. One of its main shortcomings is the poor quality of images, which are affected by speckle noise. The existence of speckle is unattractive since it disgraces image quality and affects the tasks of individual interpretation and diagnosis. An appropriate method for Gaussian reduction is one which enhances the signal-to-noise ratio while conserving the edges and lines in the image. Weiner filter was adopted for filtering in the spectral domain, but the classical Wiener filter is not adequate as it is designed primarily for additive noise suppression. Recently there have been many challenges to reduce the additive white Gaussian noise using wavelet transform as a multi-resolution image-processing tool. Gaussian noise is a high-frequency component of the image and appears in wavelet coefficients.

\[
f(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}
\]

Figure 4: Gaussian Noise

6. RESULTS

1. Using Bior 1.5 Wavelet Transform technique for Gaussian corrupted images
PSNR of Restored Image = 70.0909
MSE of Restored Image = 0.3258
Elapsed time is 2.989225 seconds

2. Using Adaptive Histogram Equalization technique for Gaussian corrupted images

PSNR of Restored Image = 71.7337
MSE of Restored Image = 0.4951
Elapsed time is 4.106553 seconds

3. Using Deconvolution Weiner Filter technique for Gaussian corrupted images
Table 1:

<table>
<thead>
<tr>
<th>Techniques</th>
<th>PSNR</th>
<th>MSE</th>
<th>Elapsed Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>bior1.5 wavelets Transform</td>
<td>70.0909</td>
<td>0.3258</td>
<td>2.989225</td>
</tr>
<tr>
<td>Adaptive Histogram Equalization</td>
<td>71.7337</td>
<td>0.4951</td>
<td>4.106553</td>
</tr>
<tr>
<td>Deconvolution Weiner Filter</td>
<td>74.9022</td>
<td>0.2387</td>
<td>2.723694</td>
</tr>
</tbody>
</table>

Chart 1: Analysis PSNR, MSE and Elapsed Time of coins images corrupted by Gaussian noise images.

7. CONCLUSION AND FUTURE SCOPE

Discrete wavelet transform will be applied to construct the detail and approximation coefficients and after multilevel decomposition and filtering, reconstruction image will be created using reconstruction coefficients. In future, work can be done to implement this algorithm of multiresolutional analysis presented in this thesis on other types of medical imaging like CT scan, MRI and EEG images under various different kinds of noise like speckle noise, gaussian noise, etc. Also, this work could be implemented on an FPGA to build an intelligent model that could be used for denoising in ultrasound images. Work could be done to minimize the constraints and resource utilization on FPGA implementation of this model.
REFERENCES:


