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COMPRESSION AND DE-NOISING OF AN IMAGE USING WAVELET TRANSFORM

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Abstract— **Image is an artefact that depicts visual perceptions. The value of data in the images gets depreciated while transferring from one medium to another medium. This occurs mainly through the sensors. In the technical terms of Image processing, these changes are termed as noises. A noise in an image is a random change in the brightness or color information in the images. The main objective is to carry out the process of Image De-noising which is the removal of noises in a digital image that has been already contaminated by an Additive White Gaussian Noise (AWGN). Additive White Gaussian Noise is a linear combination of Gaussian noise and White noise. Gaussian noise is a statistical noise which has its probability density function (p.d.f) equal to that of the normal distribution which is also known as the Gaussian distribution. White noise is a random signal with a flat power spectral density. This paper describes an algorithm for a wavelet based image de-noising as well as compression which employs the method of Fourier transformation and Error finding methods.**

Index Terms— **Noise, Additive White Gaussian Noise (AWGN), Gaussian noise, white noise, Wavelets, Thresholding, Constrained Least square(CLS)[1] method.**

I. INTRODUCTION

An image is an impression that is usually caught by highly developed technological devices like SLR camera, DSLR camera, digital camera, mobile camera, etc. Even though modern technologies have been developed in a long process, the actual impression of a person, a place or anything could not be achieved through these devices. The dimensions of images are represented in Pixels. Pixels are the physical point that represents an image on the screen. The address of the pixel corresponds to an image's physical co-ordinates. Images are affected by the "Noises" which are termed as the random changes in the color brightness of an image. There exists a strong relationship between the noise of an image and the pixels. The more the pixel of an image, the lesser the noises present in it. There are various types of image noises such as Amplifier noise, Salt-and-pepper noise, Shot noise, Quantization noise, Film grain, Anisotropic noise, White noise, Gaussian noise. The noises in images are removed by the process of Image de-noising.

The history of Image de-noising years back to 1970s. The process of image de-noising was first developed by Nasser Nahi at USI in early 1970's through his work "Statistical Image Enhancement". In later 1970's the work improvisation was made by S. Zucker and A. Rosenfeld with their paper titled "Iterative Enhancement of Noisy images" and Tom Hang with his paper "Picture processing and Digital filtering". Later in 1980, the invention of wavelet transforms made dramatic progress in the process of image de-noising. This is evident with the works of Simoncelli and Adelson's 1996ICIP paper "Noise Removal via Bayesian wavelet coring", UIUC group's SPL1999 paper, ICIP2000 paper, Vetterli and his group's TIP2000 paper and Portilla et.al's TIP2003 paper on GSM de-noising.

The curve-let transform which is a class of geometric wavelets has also found promising application into image de-noising. White noise is the most common problem found in every digital image. The first film photo registered during 1957 by a computer was an image of a three-month-old baby and it was registered in pixels-30,976 to be exact (176 x 176). The best method used in image de-noising is the wavelet transform method which involves the following basic steps:

$$X=S+N$$

Where X=Noisy signal
S=Original signal
N=Noise

$$X1=S+N1$$
$$X2=S+N2$$
.
.
$$Xn=S+Nn$$

This paper consists of an introduction part in Section I, Related works in Section II with various methods being discussed in detail, Proposed algorithm in Section III, Analysis of Wavelet method in Section IV and finally with the conclusion and Result.

II. RELATED WORKS

The two basic methods commonly used in image de-noising are spatial filtering method and transform domain filtering method. Of these two methods, the most commonly proposed one is the spatial filtering method. The process of filtering has its origin in the Fourier Transform for signal processing in the frequency domain. Spatial filtering is a filtering operation based on the Fourier Transform which acts on the pixels of an image directly. The spatial filtering process consists of moving the filter mask from one point to another point in an image. Given a point (x , y) in the xy-plane, the filter response is calculated by using the pre-defined relationship. There are various types of spatial filtering which include Linear spatial filtering, Non-Linear spatial filtering, Smoothing spatial filtering and Sharpening spatial filtering.

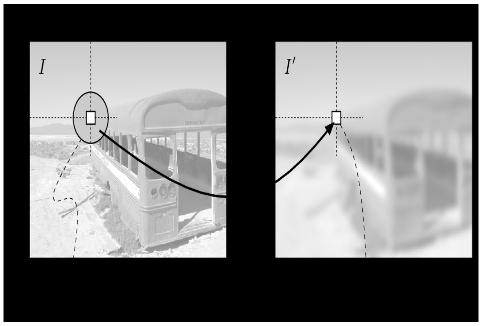

Fig.1: Spatial filtering representation

The Linear filtering method proceeds in the following way:
STEP1: Consider the image as f.
STEP2: The size (pixel) of the image is taken as M x N.
STEP3: Consider the filter mask of size m x n.
Using Linear square formula and graph methods, the filtering process is being carried out.

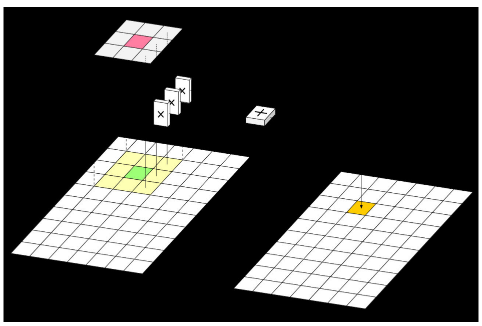

Fig.2: Working of Linear filter.

The process of *Linear filtering* is similar to a frequency domain concept called *convolution. Non-Linear spatial filtering* operates on neighboring points in an image but the only difference is that it is obviously based on the values of the pixel in the neighborhood point which is being considered.

Smoothing spatial filtering is mainly used for blurring and for noise reduction of images. In this type of filtering noise reduction starts with the blurring process where removal of small details from an image occurs prior to object extraction and bridging of small gaps with lines and curves.

Fig.3: Original image

Fig.4:3X3

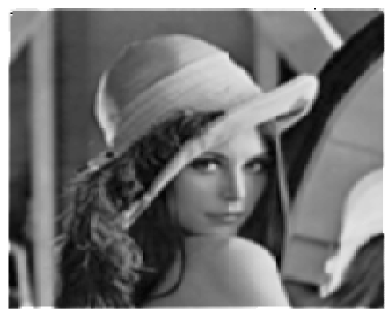

Fig.5:5X5

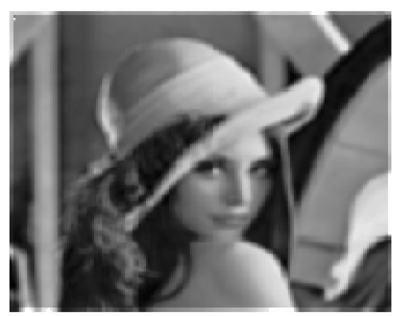

Fig.6:7X7

Figures representing Smoothing Linear Filtering

From figures 3, 4, 5 and 6 it can be clearly understood that higher the values of pixel lesser the clarity of the image.

The development of image processing is a long journey with various methods being implemented in various years. Some of the well observed methods in image processing are illustrated below.

Starting on the basis of ages, Kalman filtering method is one of the oldest methods in the image processing technique. *Kalman Filtering* method is a step by step process which forms a separable variational approximation to the joint

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posterior distribution of states and noise parameters. The general formula used in this method is

$$x_k = A_k x_{k-1} + q_k$$

$$y_k = H_k x_k + r_k$$

Where $q_k \sim N(0, Q_k)$ is the Gaussian process noise, $r_k \sim N(0, \Sigma_k)$ is the measurement noise with diagonal co-variance Σ_k, and the initial state has a Gaussian prior distribution x_0

$\sim N(m_0, P_0)$.

Transform Domain method [1] is an important technique used in image de-noising during earlier days. In this method a digital image is taken as f (m, n) where (m, n) are spatial co-ordinates represented as an N x 1 vector f= $[f_1 + f_2 + \cdots + f_N]^t$ by lexicographical ordering. Matrix-order notation is used here for the sake of simplicity. Consider the observation equation

$$g = f + x$$

where g is the degraded observation, f is the ideal image and x is the zero-mean white noise with co-variance matrix $C_n =$

$\sigma^2 I$. The *linear minimum mean square error* estimation of f is

based on the expectation operator E(.) and C_f, the co-variance matrix of f.

Local statistics which includes the work by Lee, Kuan and Frost contains various algorithms using fixed size and shape local neighborhoods which adapt the filtering techniques on a small square area using around the noisy pixel. The strategy used here is that neighbourhood of the pixel which is useful for calculating the statistical measures is chosen to obtain the central pixel according to a filter based on those statistics.

Frequency Domain method [7] is another well-developed process which is purely based on Fourier Transformation concept.

Frequency Domain Filtering Operation

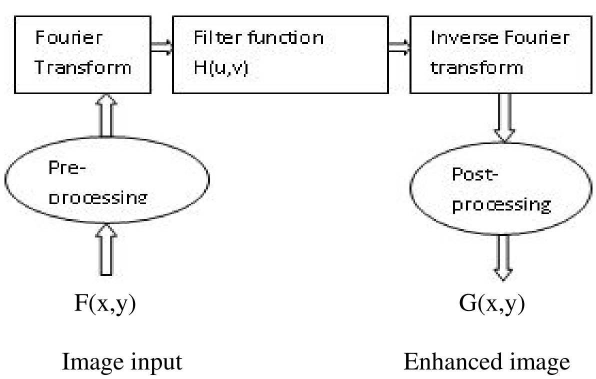

Fig.7: Represents Fourier method.

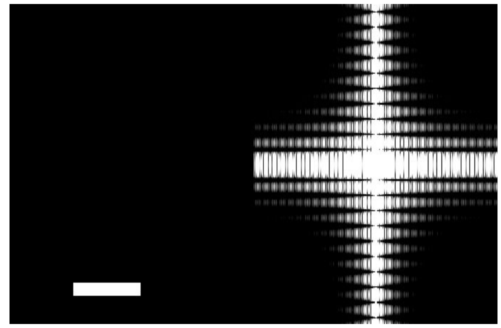

Fig.9: Shifted zero-frequency Fourier transform.

The Fourier transform admits a fast implementation when the image sizes are powers of 2.

The de-noising of image enables us to represent the signals with high degree of sparcity. We can use the **Gaussian** based model here which is used to perform combined de-noising and compression of images. The procedure for de-noising image can be considered as

$$X(t) = S(t) + N(t)$$

Here S(t) denotes the uncorrupted signal and N(t) the additive noise. Now assume that *W*(¢) and W_{i1}(¢) denote the forward and inverse wavelet transform operators. Consider *D*(¢; ¸) and let it denote the de-noising operator with threshold. We are intended to de-noise X(t) to recover ˆ *S*(*t*) as an estimate of S(t). We can summarize the procedure in three steps

Y = *W*(*X*)
Z = *D*(*Y*; ¸)
ˆ *S* = W_{i1}(*Z*)

D (¢; ¸) being the thresholding operator and '¸' being the threshold.

The *Threshold* method is being used for the reduction of noisy image. This method is very simple and efficient for the noise reduction. Under this method, two types of thresholding are used. They are soft and hard thresholding.

Hard thresholding [2] is a procedure that is more intuitively appealing whereas the soft thresholding shrinks the coefficient into the absolute value. In the soft thresholding there were three techniques *Visu shrink*, *Sure shrink*, *Bayes shrink*. *Visu shrink* is done by applying the universal threshold. The threshold was given by *¾p2logM* where *¾* is noise variance and M is the number of pixels in the image.

The Generalized Gaussian distribution (GGD) is a good model for the distribution of wavelets. The GGD is used for finding the variance in each shrinks. Finally, the result for the Generalized Gaussian distribution was found to be that *Sure shrink* is inferior compared to the *Bayes shrink*.

GGD is an exact representation of the wavelet coefficients in a sub-band. The coefficients of the low resolution sub-band are quantized after being considered as the uniform distribution.

Finally, when the image de-noising process based on wavelets is compared with different de-noising schemes, it is being clearly revealed that *Visu shrink* method is the least effective method than all other methods. *Visu shrink* is based on the universal threshold and not the sub-band adaptive unlike the other shrink schemes.

The best performance was given by the *Bayes shrink* as the distribution of coefficients in the sub-band is done through GGD. The MMSE performs slightly worse than the *Bayes shrink*. Due to this compression the quantization error occurs. The sure shrink has the highest MSE.

The *wavelet thresholding* [4] [5] is considered as an effective method for de-noising the noisy signals. Under the soft thresholding technique, there are three methods of shrinks in which the *Bayes shrink* is found to be the best of all. The *Bayes shrink* even though be the best case for the de-noising image, the *Sure shrink* Gaussian based on MMSE de-noising adapts well and discontinues in the signal.

In the year 1992, a French geophysicist, Jean Morlet introduced the concept of "*wavelets*". A wavelet is a small wave and is an oscillation that decays quickly. The *Wavelet transform* [3] [6] [8] [9] is used for the compression of digital image files as smaller files are important for storing image files with less memory space. This enables the user to transmit files faster and more reliably. The most commonly used method in the wavelet transformation is the Haar Transform representation. The Haar transform begins with the decomposition of a signal, say eight-point signal x(n), into two four-point signals.

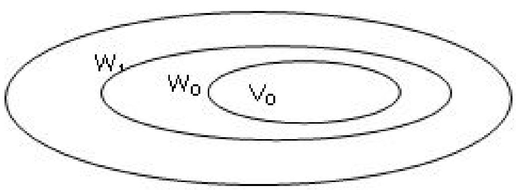

Fig.7: Wavelets spans the difference between any two adjacent scaling sub-spaces.

The two signal point can be written as

$$C(n)=0.5x(2n) + 0.5x(2n+1)$$
$$D(n)=0.5x(2n) – 0.5x(2n+1)$$

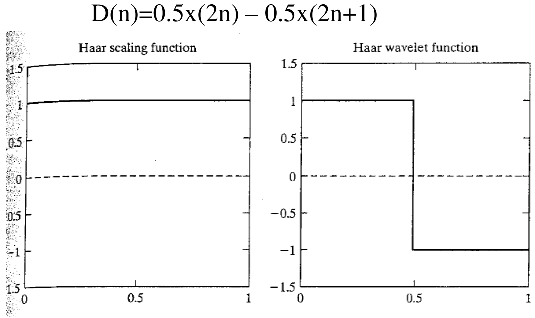

Fig.8: An Example of Haar scaling function.

III. ANALYSIS

In comparison with all the types of de-noising methods, Wavelet Transform has many advantages of which some can be outlined. One of the major advantages of the Wavelet transform over the other methods is that the time and the frequency domain can be located simultaneously. Using fast wavelet transform, it can be computed very fast. Since wavelets are the minute part, they are capable of separating the fine details in an image. Small wavelets are used to isolate the fine details in a signal whereas the large wavelets can identify the coarse details. The component wavelets of an image can be easily obtained using wavelet transform. Wavelet transform can also be used to represent functions with discontinuity and sharp peaks. It can be used for accurately deconstructing and reconstructing the finite, non-periodic and non-stationary signals. The greatest achievement by the wavelet transform is it can be used to obtain a good approximation of the given function f using only a few coefficients. A compressed or a noiseless image can be obtained using Wavelet transform without much depreciation in the quality.

IV. COMPRESSION AND DE-NOISING TECHNIQUE

The algorithm for the image de-noising process requires the understanding of Fourier Transformation method. The whole method can be described using the following steps:

Step 1: Obtain the image from the user.

Step 2: Identify the dimension of the image.

Step 3: Consider the image as a function f (x, y) of size M x N.

Step 4: Identify if the image is affected with the noises (by visibility mode).

Step 5: Get the input from the user at what size the image is being required.

Step 6: Compress the image to decrease the size occupied by it. Earlier single pixel will be occupied in the single bit of the image. After compression more pixels will be occupied in the single bit size of the image.

Step 7: During compression certain noises will be added to the image. Segment the components of the image.

Step 8: Segmentation results in the separation of the whole image into partitions or regions.

Step 9: Components are nothing but RGB values of the image.

Step 10: It is easy to identify the noisy areas of the image now.

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Step 10: Now altering the compression ratio and components can be corrected.

Step 11: Finally an ensemble of the corrected components give a compressed and a noiseless image.

Interestingly, segmentation process can be done using wavelet methods. Using discrete wavelet formula the image can be separated into minute details which will make the process simpler.

Table 1: Compared values of PSNR and Compression ratio.

Compression Ratio (%)	**PSNR (dB)**
99.435	304.76
99.612	251.08
99.387	229.09
99.015	243.69
98.845	240.01
99.376	247.62
98.927	225.10
98.389	252.92
98.276	219.9
98.176	173.3
98.096	251.01
99.198	229.12
99.215	253
99.100	262.29
98.432	248.86
98.798	250.15
98.693	260.86

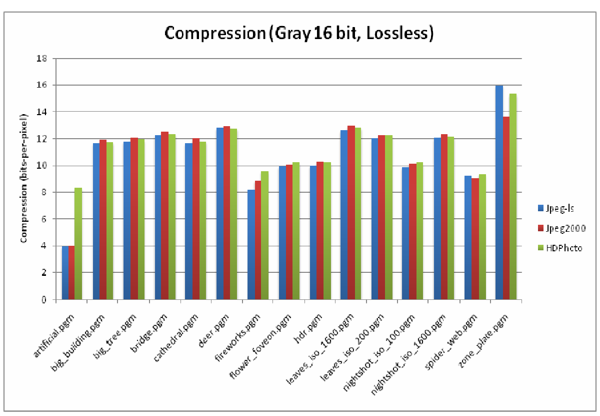

Fig.9: Compression on 16 bit gray scale image.

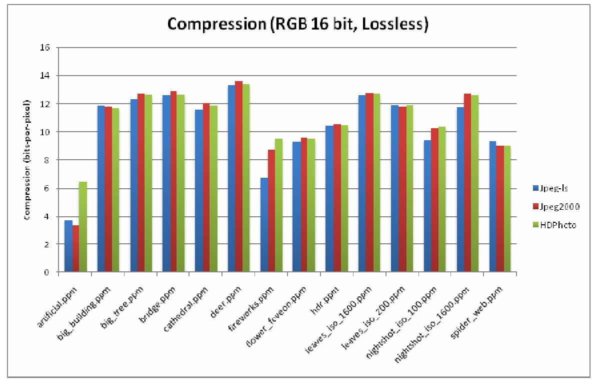

Fig.10: Compression on 16 bit RGB image.

The compression and PSNR table clearly shows the details of their corresponding values. It can be interpreted that depending on the compression ratio the resolution of the image can be changed and made clear.

Here, the dimensions are nothing but the pixels of an image. It is easy to be obtained while uploading the image itself. For example, if the dimension of an image is 245 x 345, assign M = 245 and N = 345.

It has been already mentioned in the Wavelet Transform method that a compressed image will have less noises in it. The compression of the image can be done easily using the MSE and PSNR formula given as follows

$$\mathbf{MSE = 1/MN \{\sum \sum [I(x, y)-I'(x, y)]\}}$$

$$\mathbf{PSNR = 2*\log 10(255/sqrt(MSE))}$$

Where MSE is the Mean Square Error and PSNR is Peak Signal to Noise Ratio.

Thus the noisy input image is put into many transformations and finally received back without noises. The input image not only cleared of noises but also compressed in size for easy transmission and storage.

Input image:

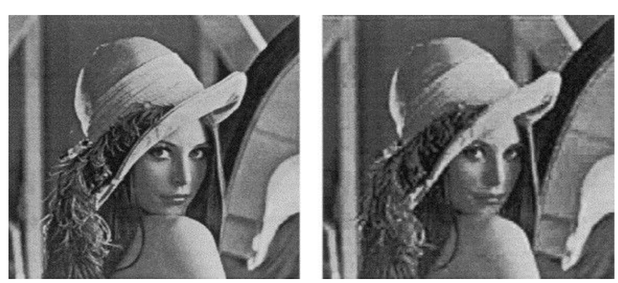
Fig.11: Image with noises and of size 60 kB.

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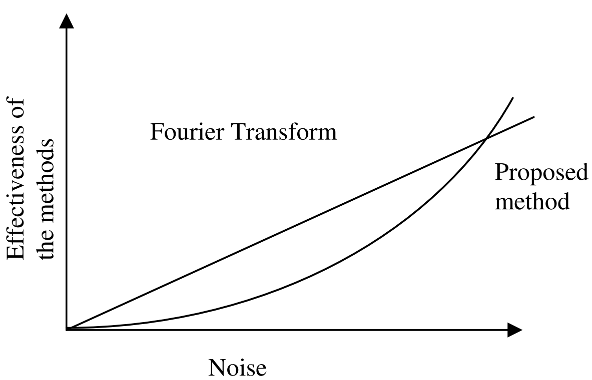
Output image:

Fig.12: Image without noises and of size 30 kB.

V. RESULT

The comparison between the proposed method and the last effective method Fourier Transform method can be illustrated as a graph shown below:



Graph 1: Comparing two methods.

When the noise level is low, the proposed method's effectiveness is low whereas it gradually increases with the level of noises. The main objective is to obtain a noiseless and a compressed image which is already been implemented and successfully obtained through the proposed method using wavelets.

VI. CONCLUSION

The proposed method is effective in de-noising the image as well as compressing it for easy storage. The user has the control to manage and design the whole image. The implementation can be made effective through various algorithms using programming language concepts. The paper contains an easy adaptive nature to the wavelet forms and its usage. Overall, this method can be easily understood and can be effectively implicated.

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