Image Encryption and Comparative Compression Analysis using DCT-DWT

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Abstract—Now a days image compression has become is an indispensable part of digitized image storage and transmission. Compression of an image is necessary before storing and transmitting it due to its limitation of storage and bandwidth capacity. Wavelet transform decomposes complexion of images into its elementary forms. In this paper, a comparative study has been carried out on image compression using DCT (Discrete Cosine Transform) and DWT (Discrete Wavelet Transform). A comparison is outlined to emphasize the results of this compression system between DCT and DWT using JPEG (Joint Photographic Experts Group) and PNG (Portable Network Graphics) color images. We have done conversion of color images into gray scale and also compression of gray scale image is shown after conversion using DWT method. DWT algorithm performs much better than DCT algorithms in terms of Compression, Mean Square Error (MSE) and Peak Signal to Noise Ratio (PNSR).

Keywords:- DCT; DWT ; PSNR; MSE; Wavelet Transform; Image Compression; Huffman Coding; JPEG;PNG; Compression ratio.

I. INTRODUCTION

An image can be defined as a matrix of pixel or intensity values. Image compression is used to reduce the redundancy and randomness present in the image because to increase the storing capacity and efficiency level of the images. Therefore it is essential to compress the images by storing only the required information needed to reconstruct the image. To compress any image, redundancy must be removed. Sometimes images having large areas of same color will have large redundancies and similarly images that have frequent and large changes in color will be less redundant and harder to compress. The main objective of this paper is to reduce irrelevance and redundancy of the JPEG and PNG image data in order to be able to store or transmit data in an efficient form using DCT and DWT. We have tried to study the different image compression algorithm and evaluate their performance on different image formats and also developed a system for image compression using Discrete Wavelet Transform and compare the results with the existing techniques or systems. Image compression can be done in two ways:

- Lossy Compression
- Lossless Compression

If any pixel value is changed from a digital image and then energy will be lost and this technique is called 'lossy' compression. The amount of information retained by an image after compression and decompression is known as 'lossless' compression [7]. In this research paper, a modified and efficient image compression scheme is proposed based on DWT and which results a good compression ratio without degrading the quality of the image. The proposed algorithm has been analyzed and compared with some other existing methods. Several quality measurement techniques like PSNR and MSE have been considered to determine the image compression with respect to the reference image. For that purpose some traditional images are taken and have done experiment on it [1-3]. This paper structure contains the following sections: section 2 describes the previous work done by different authors, section 3 describes the basic principles of image compression techniques, section 4 illustrates the fundamentals of wavelet transform, section 5 presents the proposed method using DWT, section 6 demonstrates the experimental results and discussions and finally section 7 winds up the paper.

II. RELATED WORKS

Image compression has many practical applications because of huge data storage, transmission and retrieval for medical imaging, documents and videoconferencing. Chowdhury and Khatun [1] described the performance of the image compression algorithm and provide sufficient high compression ratios compared to other techniques. Sukanya and Preethi [2] have described about compression methods such as JPEG 2000, EZW, SPHIT (Set Partition in Hierarchical Trees) and HS-SPHIT (Highly Scalable-SPHIT) on the basis of hierarchical time, error comparison, MSE, PSNR and compression ratio. Qureshi [8] in his Computational Project 'Image Compression using Wavelet Transform' explained how wavelets can be used in image compression. Ananda Narayan and Srivastava [9] proposed a technique for image compression where Huffman coding is used to compress an image then chooses edge detection to identify and locating sharp discontinuities in image. Averbuch et al. [3] have tested several compression techniques and 512X512 images are trained together and common table codes were created to achieve a compression ratio 60-65 and a PSNR of 30-33 and compression ratio 35-36 and a PSNR of 35-37. Talukdar and Harada [4] in their paper described the 2D Discrete Wavelet Transform (DWT) and the detail matrices from the information matrix of the image have been estimated. Wavelet Transform is used in the reconstructed image and amalgamated by the estimated detail matrices and information matrix. The compression quality of the images has been calculated using Compression Ratio (CR), Peak Signal to Noise Ratio (PSNR), Mean Opinion Score (MOS), and Picture Quality Scale (PQS).

III. IMAGE COMPRESSION TECHNIQUES

The basic encoding method for transform based compression works as follows:

1) Image transform: Divide the source image into blocks and apply the transformations to the blocks.

2) Parameter quantization: The data generated by the transformation are quantized to reduce the amount of information. This step represents the information within the new domain by reducing the amount of data. Quantization is in most cases not a reversible operation because of its lossy property.

3) Encoding: Encode the results of the quantization. This last step can be error free by using Run Length encoding or Huffman coding. It can also be lossy if

it optimizes the representation of the information to further reduce the bit rate.

Transform based compression is one of the most useful applications. Combined with other compression techniques, this technique allows the efficient transmission, storage, and display of images that otherwise would be impractical [4].

4) DCT-Based Transform Coding

The DCT was first applied to image compression in the work by Ahmed et al [5]. It is a popular transform used by the JPEG image compression standard for lossy compression of images. Since it is used so frequently, DCT is often referred to in the literature as JPEG-DCT, DCT used in JPEG. JPEGDCT is a transform coding method comprising four steps. The source image is first partitioned into subblocks of size 8x8 pixels in dimension. Then each block is transformed from spatial domain to frequency domain using a 2-D DCT basis function. The resulting frequency coefficients are quantized and finally output to a lossless entropy coder. DCT is an efficient image compression method since it can decorrelate pixels in the image and compact most image energy to a few transformed coefficients. JPEG and PNG may be replaced by wavelet-based image compression algorithms, which have better compression performance [5].

IV. THE WAVELET TRANSFORM

A wavelet is a mathematical function used to divide a given function or continuous-time signal into different wave signals. It can assign a frequency range for each wave signals. All wave signals that match its scale can be analyzed with a resolution. It is the delegation of a function by wavelets.

$$\varphi_{(a,b)}(t) = \frac{1}{\sqrt{a}}\varphi\frac{(t-b)}{a} a, b\epsilon R, a \neq 0$$

Where is a function called wavelet, a, is another function which measure the degree of compression or scale, and b, is a translation function which measures the time location of the wavelet.

A. Quantization: Quantization is the process where actual reduction of image is done. It is a lossy compression technique which basically used in DCT data quantization and DWT data quantization for JPEG and PNG images.

B. Entropy Encoding: Entropy encoding is a lossless data compression method. Two commonly used entropy encoding techniques are Huffman coding and Arithmetic coding.

C. Discrete Wavelet Transform (DWT): Suppose a function f(x) is a continuous function and expanded in a sequence of numbers, then the resulting coefficients are called the Discrete Wavelet Transform (DWT) of f(x) [2].

V. ENCRYPTION MECHANISM

The Encryption Mechanism is instigated using **Adaptive Pixel Transformation** which is described in an algorithmic form below:

Adaptive Pixel Transformation is mathematically demonstrated as:

1) Load Image that is to be encrypted and let it be denoted by X
1. Get the dimensions describing the size of the image. Store them and term them as (i, j, k).
2. X→ g(i,j,k) where g denotes the function describing dependence of the original image of (i,j,k).

3. Now, based on the vales obtained above i.e. (i,j,k), design an adaptive key generating mechanism that would yields different keys as the image values (i,j,k) change
4. Let such as key be Key=h(i,j,k) where h is the mathematical function for key generation
5. Based on the obtained values of the image parameters and the key values, design an encryption mechanism that would adaptively change with the change in encryption mechanism designated by the transformation:

$$Y \rightarrow z'(I,Key).$$

Filter Design Aspects:

While designing an Image Filter that would filter out degradations, it is important to keep in mind the following aspects about Noise and filters. Pdf represents the probability density function of the random variable X

1) All noise types need to be equally-probable at all frequencies
2) Filters themselves can introduce errors and degradations in case of non-linearity and space invariance
3) No practical filter can satisfy the above two conditions ideally and at the most may emulate the performance to a large extent.
4) The filter chosen must be chosen in such a way that it tries to replicate the above parameters as much as possible
5) The Wiener Filter is one that to a large extents satisfies the above requirements although its by no means an ideal filter.
6) Degradations may still be present even after filtering since no practical filter can swipe out all degradations.
7) It is imperative to check performance metrics such as Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) so that the residual degradation can be estimated for applications.
8) The filter should be such that it must be practically realizable.
9) The filter should not render instability to the system
10) One such Filter that satisfies such conditions to a large extent is the Wiener Filter

The most important feature of the Wiener Filter can be explained as:

Linearity: This means that the filter input-output response curve follows a straight line curve, the inference which can be drawn from it is the fact the filter treats all pixel values equally.

Space Invariance: This means that for a spatial shift (x,y) in the input to the filter, there is an equal shift in the output of the filter.

It should be noted though that no practically existing filter can be found such that it depicts the above mentioned properties completely. The Wiener Filter is also no exception to the above facts and has spectral limitations like any image filter.

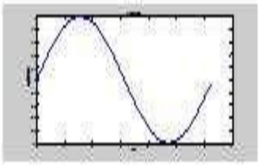
Image Compression

Image compression is a technique which is useful for reducing the amount of data describing the images. Image compression has the following benefits:

1) Lesser Data for storage
2) Lesser data rate of bandwidth needed for transmission.

Here we analyze to techniques for the compression of images v.i.z. the discrete wavelet transform (DWT) and the discrete cosine transform (DCT)

The Discrete Wavelet Transform (DWT)



The mathematical description of the wavelet transform can be given by:

$$C\,(S, P) = \int_{-\infty}^{\infty} f(\mathrm{t})\;((S, P, t))dt$$

Here S stands for scaling
P stands for position
t stands for time shifts.
C is the Continuous Wavelet Transform (CWT)

The main disadvantage of the CWT is the fact that it contains an enormous amount of data. The sampled version of the CWT is the Discrete Wavelet Transform (DWT). The DWT is a down sampled version of the CWT and its characteristic nature is to smoothen out abrupt fluctuations which are possible due to both abruptly changing base functions and down sampling.

The Discrete Cosine Transform

The DCT is defined as:

$$y(k) = w(k)\sum_{i=1}^{N} x(n)\cos\left(\frac{\pi(2n-1)(k-1)}{2N}\right)$$

Here
$w(k) = 1/\sqrt{N}$ for k=1 and
$w(k) = \sqrt{2/N}$ for 2< k<N
The main benefit of the Discrete Cosine transform is the fact that it removes the spectral redundancies in the ECG signal thereby making it more compact. The result is lesser redundant information in the signal. Thereby the information content in the signal is more, and can be given by:

$$I=\log_2(1/P_i)$$

VI. RESULTS AND DISCUSSIONS

The various steps in the image encryption, compression, noise removal, decompression and decryption process can be graphically illustrated which would make the concept more palatable. The test image taken for this study is len.jpg.. Results obtained using the proposed algorithm has been shown below. **A critical explanation of the results obtained follows the figures.**

Fig.6.1 Test Image

Fig.6.2 Compressed image using DCT

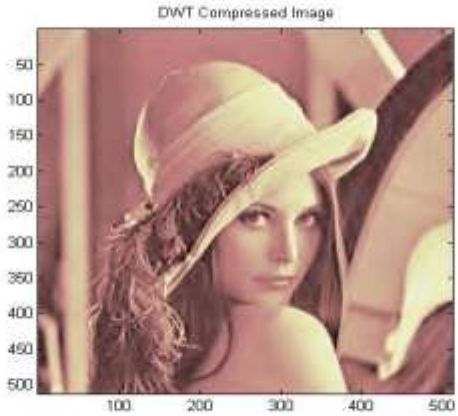


Fig.6.3 Compressed image using DWT

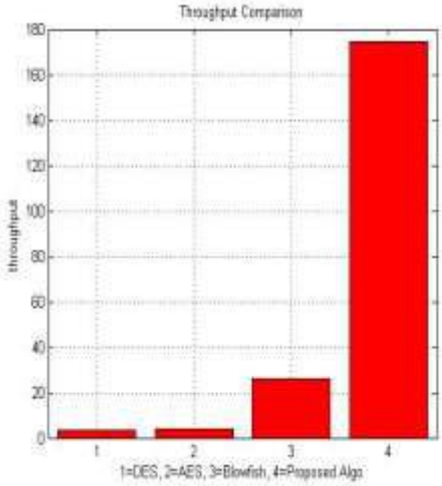


Fig.6.6 Comparative Throughput for Standard Encryption Algorithms

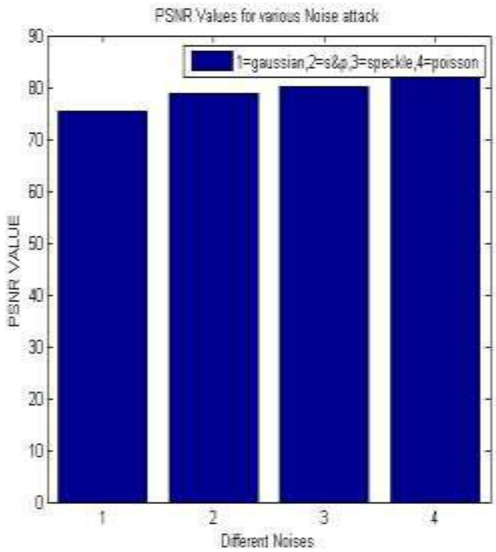


Fig.6.4 PSNR Values for Different Noise Effects

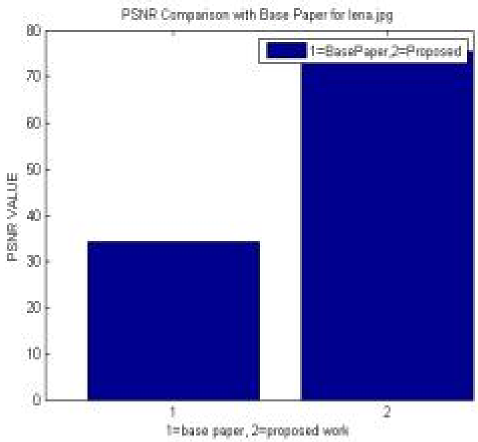


Fig.6.7 PSNR Comparison with Base Paper (Securing the architecture of the JPEG compression by image encryption by Faiq Gmira et.al IEEE, 2015) for Lena.jpg

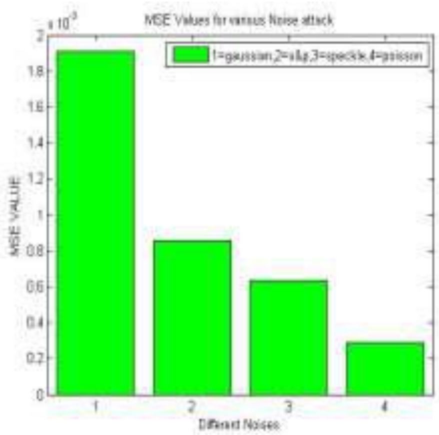


Fig.6.5 MSE Values for Different Noise Effects

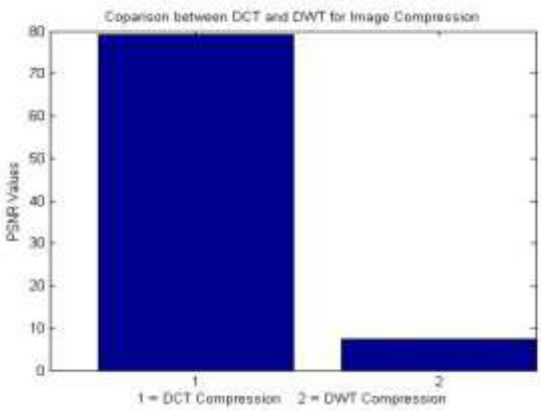


Fig.6.8 Comparative PSNR values for DCT and DWT

The results can be interpreted as:

Figure 6.1 shows the original image that is loaded to the MATLAB workspace. The figure is a standard test image, (lena.jpg).

Whenever an image passes through a wireless channel, it undergoes some degradation called noise. The ratio of Signal Power to Noise Power is called Signal to Noise Ratio (SNR), the inverse of which is called Noise to Signal Ratio (NSR). Image de-noising or restoration essentially resorts on the statistical parameters of the noise effects such as mean, variance, noise density etc. Utilizing the noise parameters helps in the accurate design of the Noise Filter (Wiener Filter in this case). In case the statistical properties of noise are not known, the filter is used under the zero noise assumption resulting in zero NSR. Signal to Noise Ratio (SNR) is not considered in this case because zero noise would result in infinite SNR. Hence zero NSR is a more appropriate parameter in case of vanishing noise effects.

Figure 6.4 and figure 6.5 show the values of PSNR and MSE for the different noise effects. Figure 6.6 shows the comparison of throughput of the proposed algorithm with standard encryption algorithms such as DES, AES and blowfish.

Figure 6.7 show the comparison of PSNR with the base paper (Securing the architecture of the JPEG compression by image encryption by Faiq Gmira et.al IEEE, 2015). The comparison shows substantial improvement in the PSNR values.

Figure 6.2 and figure 6.3 depict the images after compression using Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) respectively. Finally figure 6.8 depicts the comparative PSNR values for compression using DCT and DWT respectively. It can be seen that compression using DCT attains higher PSNR. This can be attributed to the fact that compression using DWT resorts to ignoring the detailed co-efficients for compression. Hence it leads to lossy compression and lesser value of PSNR compared to DCT.

VII. CONCLUSION

In this research plan, an attempt has been made to study and compare the image compression techniques using DCT and DWT. From the above experimental analysis, it is seen that in comparison to the other experiments our experiment shows better performance with respect of compression size and percentage of image compression. A new algorithm has been proposed on Image Compression using DWT and Inverse DWT. An experimental result has been shown after compressing any color image of different image formats and finally conversion of color image into gray scale is shown. The most distinguishing feature of using DWT and Inverse DWT is that it will not only enable to compress an image but also will help to maintain the quality of the image as it was in its original form, which was hardly possible earlier in other image compression techniques. The future direction of this research is to develop such an algorithm where any random image of any resolution or size could be compressed at a uniform rate without degrading the quality of image.

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