OPTIMIZING THE WAVELET PARAMETERS TO IMPROVE IMAGE COMPRESSION

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ABSTRACT

Wavelet compression technique is widely used to achieve high good compression factor. In this paper, certain experiments were performed to identify the importance and the sensitivity of this technique to various internal and external parameters. Compression factor and SNR are the main factors to be optimized here against many factors like; image type, division factor, subblock size. Changing these parameters has shown a significant change in the performance leading to verified steps on how to choose these parameters in order to optimize the performance to get better compression and quality.

KEYWORDS: *Image compression, Wavelet, Transformation, Coding, Information theory, entropy.*

I. INTRODUCTION

Uncompressed multimedia data like graphics audio and video signals requires a considerable storage capacity and high transmission bandwidth. Despite rapid progress in mass-storage media, processor speeds and performance of digital communication systems demand for data storage capacity and data-transmission bandwidth continues to outstrip the capabilities of available technologies [1], [2]. The recent growth of data intensive multimedia-based web applications has not only sustained the needs for more efficient ways to encode signals and images, but has also made a significant progress in compression of such signals and communication technology [3]. Various data types require different recourses for storage and transmission. A simple text may require few Kilo bytes of storage space and needs few second for transmission over a typical modem. A full motion video signal requires few Gega bytes of storage space and few hours to transmit the signal over the same modem. Certain data needs sufficient storage space, large transmission bandwidth and long delay for the transmission time. At the present state of technology, the only solution is to compress multimedia data before being stored or transmitted [4].

Compression techniques can be classified as lossless or lossy compression methods where the original representation is recovered perfectly or with certain degradation. This is very important in applications like medical or astronomical images where an image is processed by computing devices instead of human eyes. There are several lossless compression algorithms like Run Length Encoder (RLE), Lempel-Ziv Welch (LZW) and Huffman encoding methods. Lossless compression can only achieve a modest compression factor. On the other hand, an image reconstructed following lossy compression contains degradation relative to the original one. This is often due to the compression scheme which may completely discard redundant information. However, lossy schemes (like DPCM and DCT) are capable of achieving higher compression factor than lossless schemes [5].

Wavelets are functions defined over a finite interval and having an average value of zero. The basic idea of the wavelet transform is to represent any arbitrary function as wavelets or basis functions [6-8]. These basis functions or baby wavelets are obtained from a single prototype wavelet called the mother wavelet.

JPEG is a lossy compression technique that the decompressed image is not quite the same as the one started with. JPEG is designed to exploit known limitations of the human eye. Thus, JPEG is intended for compressing images that will be looked at by humans. Whereas wavelet-based coding provides improvements in picture quality at high compression ratios depending on the factors used in compression. There are no critical losses in data, so one can retrieve approximately the original image with less size. Hence, wavelet is used in applications like Fingerprint compression, Musical tones, Detecting Self-similarity and Denoising Noisy Data [9-10]. Moreover, wavelet transform is being used in many other applications especially in signal and image processing tasks like the numerical description of texture via the discrete wavelet, among many other applications [11-14].

The rest of this paper is organized such that Section 2 reviews the standard Wavelet Transformation, algorithm, various parameters and its applications; it also refers to certain recent related work. Section 3 introduces the Normalized Wavelet Transformation where the algorithm and certain testing criteria are presented. Section 4 shows the obtained experimental results under various conditions using software analysis. Section 5 concludes the findings of this paper and comments on it.

II. WAVELET ALGORITHM

The wavelet image compression technique is an exciting one [15-18]. Several related work is being conducted on the importance of Wavelet and its applications particularly in image processing and telecommunications. Some of these applications are in the recent and important topics like Internet, edge detection, biology, biomedical applications and signal processing in general [19-23]. This compression technique starts by reading an image as an M by N matrix then partitioning it into 8x8 blocks or some other sizes. Normalized wavelet transformation is applied to each block. The algorithm is presented in steps as follows;

1- Read the input image into an M by N matrix.
2- If the size of the input matrix cannot be divided by 8 then, add rows and columns of zero values as shown in Fig.1
3- Block the padded matrix into several 8x8 blocks as shown in Fig.1
4- Apply the normalized wavelet transform on each block
5- Reshape the resultant matrix into one dimensional vector then apply the arithmetic encoder.
6- Store the resultant stream of bits into a binary file.
7- Repeat the previous procedure until the whole image is processed

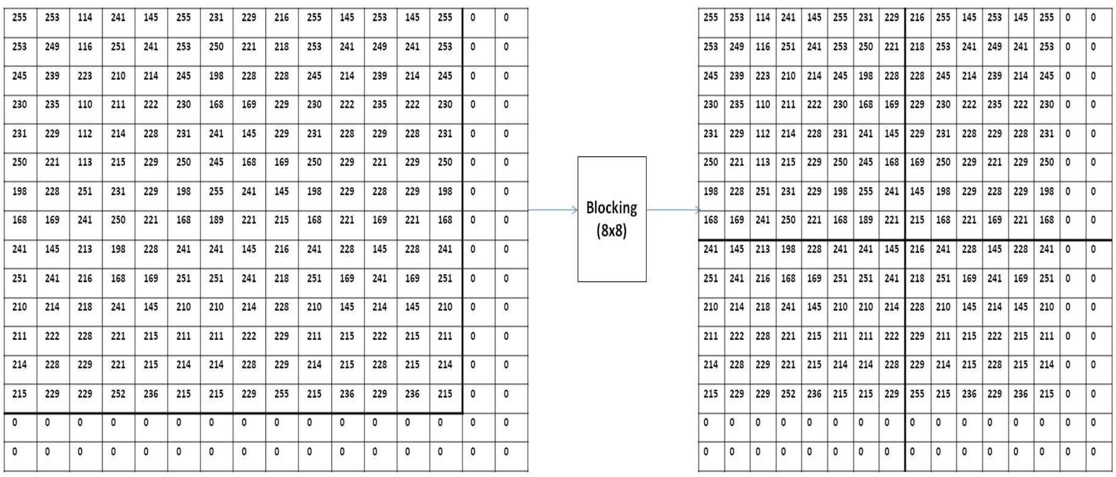

Fig. 1 zero padding and subblocking

To retrieve the original image from the compressed one, a reverse process is implemented such that the binary stream data is applied to an arithmetic decoder, then it is reshaped into an 8x8 block. Sequentially this block is applied to the inverse wavelet transformation and the complete matrix is reconstructed then the added zero rows and columns are eliminated. This procedure is illustrated through the following steps;

1- Read the binary file to a bit stream that represent the compressed image then apply it to the arithmetic decoder.
2- Reshape the binary stream into 8x8 blocks
3- Apply the decoded blocks to the inverse wavelet transform
4- Eliminate the zero rows and zero columns that were added initially.
5- Combine the sub blocks to reconstruct the full image

The normalized wavelet transform is not a completely reversible process and so the original image could not be recovered exactly.

III. NORMALIZED WAVELET TRANSFORMATION

The core of the wavelet compression technique is the Normalized Wavelet transformation which is applied to each 8 by 8 block, the steps of this normalized wavelet transformation is given as;

1. Consider each 8 by 8 block of the matrix
2. Divide the sub block by √8;
3. Consider one row at a time such as;
4. Compute the average values for the locations 1 to 8 for each row as; (1+2)/√2, (3+4)/√2, (5+6)/√2, (7+8)/√2
5. Assign these four values to the first four locations of the row
6. Compute the difference values for the locations 1 to 8 for each row as; (1-2)/ √2, (3-4)/√2, (5-6)/√2, (7-8)/√2
7. Assign these four values to the last four locations of the row
8. Repeat the process on the four average values such that they are transformed into two average values and two difference values, put these values in place of the first four locations of the row
9. Repeat the previous steps to have one average at the left and one difference next to it
10. Repeat the same process to the remaining rows.
11. The whole process is repeated for each column of the block.
12. The resultant matrix will have one average value at the left and all other values are the differences

There are several methods that are commonly used to test the performance of the compression technique. This includes; Compression Factor (CF), which is defined as size of original image divided by the size of the compressed image, and the Signal to Noise Ratio (SNR), which is defined as 10 log(signal power divided by the error power), where error signal is the difference between original and reconstructed signal.

IV. EXPERIMENTAL RESULTS

The sensitivity of wavelet compression technique for several issues is measured under several conditions. The main parameters are the image type, image size, division factor and block size. Simulation has been performed using software analysis such that one parameter is considered at a time. Performance of the algorithm was examined to illustrate how these parameters will affect the achievement of certain compression criteria such as the compression factor and the compressed file size. The simulation has been performed as follows;

1 Grayscale image: standard size grayscale images were investigated using the wavelet compression technique. The compression factor and the SNR were calculated as shown in Table 1.

Table 1 Certain image files and the corresponding CF and SNR

Image name	CF	SNR (dB)
Blood 1	3.0	36.0
Cameraman	3.4	36.7
Boat	3.8	37.9
Lena	3.6	37.5
Bacteria	3.7	37.7

Changing the size of the grayscale image does not show clearly the effect of the size on the CF and SNR. The redundancy of the data and the nature of the signal play an important role in achieving a certain amount of CF and SNR.

2 Image size: Several grayscale images, with various file size, were considered, the compression factor and SNR where examined while changing the size of the image, results were obtained as illustrated in Fig.2 respectively. The corresponding values are changing slowly as the data size changes. However, increasing the file size is not the reason after the increase in the CF value but this increment in CF is mainly due to the change in the entropy of the image file.

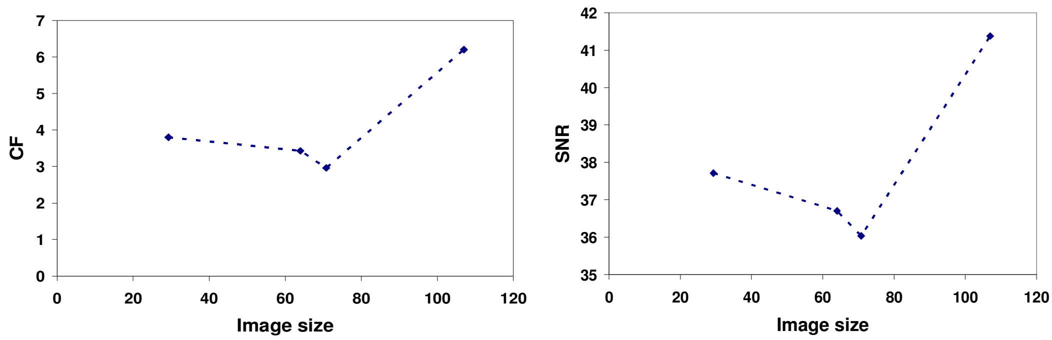

Fig.2 Effect of changing gray scale image size on CF and SNR

3 Division factor: in this case, performance has been tested on the same image files but with various division factors. The "cameraman" grayscale image was considered with a division factor of √2, resulting in a CF of 3.4 and SNR of 36.7dB. When the division factor was changed to √2.5, the CF increased to 4.21 and the SNR decreased to 2.67 dB. Obviously, increasing the division factor may result in more losses and so the SNR value may drop. The effect of changing the division factor on the performance is shown in Fig.3.

Increasing the division factor gradually from 1 to 4 has improved the CF by about 1 but the SNR has dropped by almost 30 dB resulting from a great degradation in the quality of the reconstructed image. As the division factor increases then the processed matrix contains smaller values which may be easily lost through the normalized wavelet transformation and inverse transformation processes.

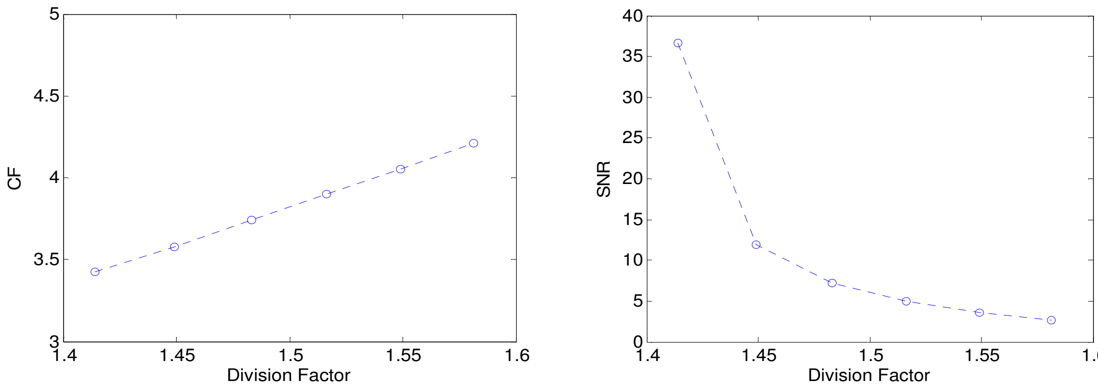

Fig.3 Effect of changing division factor on CF and SNR

4 Sub-block: as shown in the wavelet algorithm, the matrix is partitioned into 8x8 sub-blocks, considering the "cameraman" grayscale image, at this size of sub-matrix then, the CF is 3.4 and the SNR is 36.7dB. On the other hand, a 32x32 sub-block size increases the CF to 7.9 and the SNR is reduced to 27.3 dB. The effect of changing the sub block size is illustrated in Fig.4. Increasing the block size from 8 to 64 has improved the CF by almost 10 dB and the improvement was almost linear with the increment in the block size. This increase in block size means that less number of blocks are available to be treated and so less data size to be stored leading to a better CF. On the other hand, increasing the block size makes the average values and the difference values, which are use in the base functions of the wavelet transformation, far from each other and so may not be possible to retrieve the exact values after several processes. This will result in an error between the original and the reconstructed images and so SNR value will degrade.

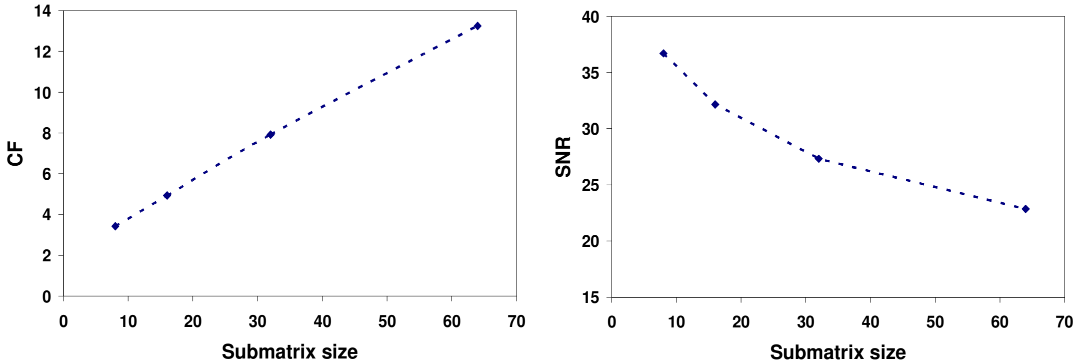

Fig.4 Effect of changing submatrix size on CF and SNR for a grayscale image

5 RGB image type: wavelet compression technique can be used with various image formats. A typical RGB image with three layers and has an original size of 531 Kbytes has been compressed using wavelet compression technique. This process results in CF of 2.6 and SNR of 35 dB.
Varying the sub block size of the RGB image has changed the CF and SNR as shown in Fig.5. This has the same performance style as that of a grayscale image type. The difference in values can be referred to the nature of the image or the amount of redundancy it may has.

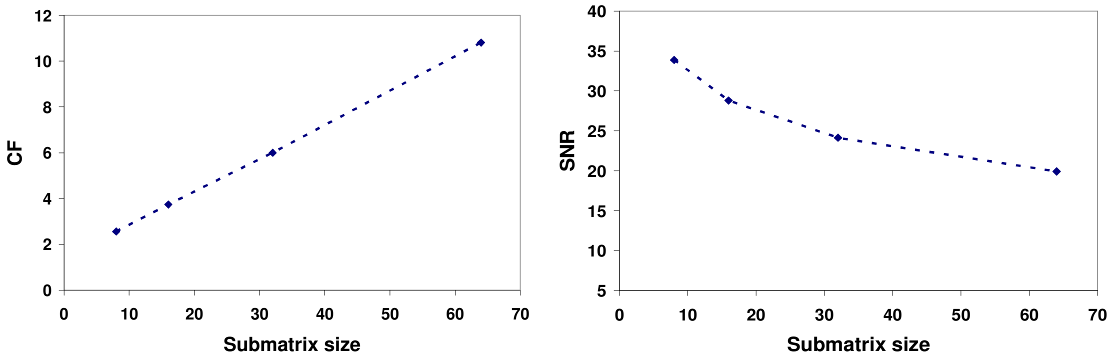

Fig.5 Effect of changing submatrix size on CF and SNR of RGB image

For the same image, the division factor has been changed and the effect of that change on both the CF and SNR is illustrated in Fig.6. Similar to the grayscale image type behavior, the CF has been improved as the division factor increases while the SNR is reduced accordingly.

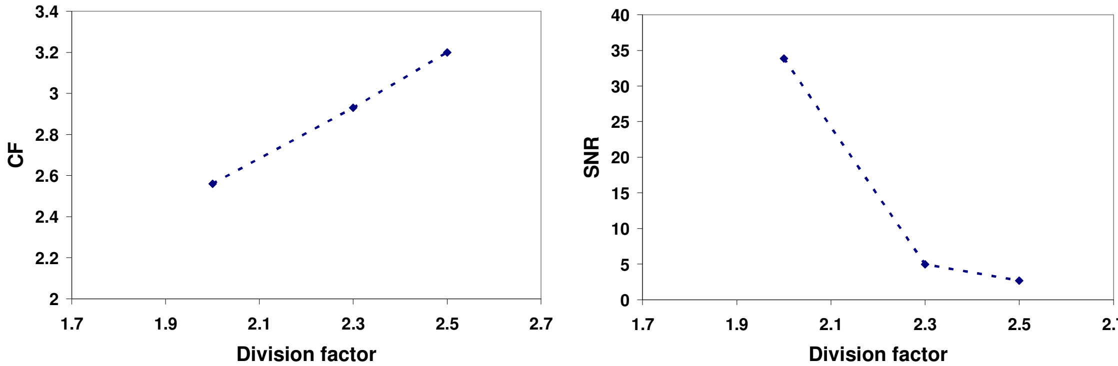

Fig.6 Effect of changing division factor on CF and SNR of RGB image

V. CONCLUSION

Wavelet coding scheme provides a good picture quality at low bit rates. This study shows the importance and the role of some effective parameters used in wavelet compression technique. The compression factor and SNR were measured and analyzed under several conditions such as; image type, image size, sub block size and division factor. Results were obtained and represented to illustrate the importance of each individual item. Although slight differences were obtained when changing the image size and type, but this is mainly due to the nature of images being used. On the other hand, increasing the division factor has shown a large degradation in the quality and so on the SNR. The sub block size has also been increased leading to an improvement of the compression factor with a small degradation in SNR. Changing the image size has no dramatic effect on the compression factor but has provided better SNR. Accordingly, one can chose the suitable values of the wavelet parameters to obtain the desired results in terms of compression factor and SNR.

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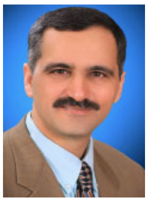

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