Image Compression Using Wavelet Methods

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Abstract: *This paper aims to study and compare the compression efficiencies of wavelet-bitmap and wavelet-Huffman. Both methods use wavelet to deduct a portion of the information in the image that can endure losing it without a significant disturbance in the image itself. Both methods deal with thresholding of wavelet coefficients to produce as much as possible zero coefficients for the purpose of higher compression, then encode the non zero coefficients by using Huffman encoding and bitmap drawing of the coefficients distribution resulted from thresholding inside the analyzed image. The processing time is calculated using MATLAB. Results were taken to compare the efficiencies of the compression between the two methods. In this work we present a method based on wavelet transforms using Huffman encoding and bitmap encoding. Different combinations of parameters and transforms have been compared. The result shows that the time of compression in wavelet-bitmap method is less than the time of compression which is taken by wavelet-Huffman method. Also the compression ratio in the wavelet-Huffman is greater than the other method. The quality in both methods is relatively equal.*

Key Words*: Image compression, wavelet-bitmap, wavelet-Huffman.*

I. INTRODUCTION

Image compression is the application of data compression on digital images. In effect, the objective is to reduce redundancy of image data in order to be able to store or transmit data in an efficient form. There have been developed many types of compression algorithms. In fact, there are two types of compression, namely lossy and lossless compression. In lossless compression techniques, the original image can be perfectly recovered form the compressed (encoded) image. These are also called noiseless since they do not add noise to the signal (image). It is also known as entropy coding since it use statistics/decomposition techniques to eliminate/ minimize redundancy. Lossless compression is used only for a few applications with stringent requirements such as medical imaging. Lossy compression technique provides much higher compression ratios than lossless schemes. Lossy compression is widely used since the quality of the reconstructed images is adequate for most applications. By this method, the decompressed image is not identical to the original image, but reasonably close to it. This work exploits an image compression based on wavelet compression method which be considered a lossy compression. In this study the wavelet compression was achieved using Huffman encoding and bitmap encoding. These compression methods that will reduce the massive storage capacity required as well transmission times without a degradation in the diagnostic contents. Compression techniques can be classified according to the difference between the original and recovered image; a lossy techniques such as a discrete cosine transform (DCT) and discrete wavelet transform (DWT) recovers images similar to the original one and achieves high compression ratio. While lossless techniques are able to accurately recover the original image although lowering the compression efficiency.

A further classification for the lossy technique can be done according to the compression algorithm involved [4, 5]. Medical image compression requires higher quality. No lossy compression method has been adopted by the health authorities as an accepted standard. This fact, together with the grey scale nature of the radiographic images motivate the researchers to promote a new developments on this field. In our approach we have chosen wavelet based technique mainly because the accepted results obtained on the previous researches [3-9] pursuing a lossy compression method can be widely accepted by the medical image specialists mainly on MRI application.

II. METHODS OF IMAGE COMPRESSION

In this work we compare the wavelet-Huffman method and wavelet-bitmap method. Also we will compare the transmission time required for the original image and the compressed image.

Lossy Compression

1. The wavelet-Huffman method. This method has three stages:

a- Discrete bi-dimensional wavelet transform [1, 2], using an extended 2D pyramidal algorithm described by Mallat [8], employing daubechi (4) filter.

b- Coefficients thresholding and quantization. The resulting coefficients from the wavelet transform are truncated with a threshold depending on the scale band. In order to remove the least significant coefficients which represent the zeros coefficients, thresholding of wavelet coefficients gives an opportunity to suppress a portion of the coefficients that do not affect the quality of the information, and setting them to zero. This will open the way for applying different methods to compress those redundant information (zeros coefficients).

Thresholding is calculated by a statistical method according to the formulae:

$$\theta = \frac{\alpha}{N} \sum^{N} |Ce_w|$$

Where α is a correction factor ranging from 0 to 1 and θ is the threshold, N represents the count of coefficients in the analyzed image. Ce_w are the wavelet coefficients [9]. In this paper, the threshold is calculated for all sub-bands. After the thresholding, the non-zero coefficients will be quantized in order to increase the repetition which increases the efficiency of Huffman encoding. If we remove the zeros coefficients by bitmap-encoding, this will approve the compression ratio [3].

c- Application of Huffman encoding on the quantized coefficients.

2. The wavelet-bitmap encodings. This method has the same procedure of the first two stages of the wavelet-Huffman encoding, but it is different from previous one because of using the bit-map encoding. After the process of thresholding, zeros and non-zeros coefficients are obtained. The zeros coefficients have a values which are either equal or less than the calculated threshold values. The idea behind bitmap is to draw a map for the zeros and non-zeros coefficients. Then the positions of zeros coefficients will be located in order to eliminate them [3]. The qualification indicates how many zeros coefficients will be eliminated. The encoded map and the original image are equal in size but certainly it depicts the positions of the zero coefficients. The bitmap also needs to be reduced in size. Then a run length encoding method is used. The run length is a very simple method used for sequential data. It is very useful in case of repetitive data. This technique replaces sequences of identical symbols (pixels), called (runs) by shorter symbols. The run length code for a gray scale image is represented by a sequence {Vi , Ri}, where Vi is the intensity of pixel and Ri refers to the number of consecutive pixels with the intensity Vi [7].In our bit map, a run length is used to encode the zeroes coefficients and a non-zeros coefficients. Furthermore, the run length encodes the zeros coefficients as a length of zeros, also a run length encodes the non zeros coefficients as a length of ones. After the elimination process of zeros coefficients, a bitmap will have only the length of one's code which has all the necessary information to retain the image.

3. DCT-Huffman method. This compression technique is based on discrete cosine transform to block of (8*8) pixels of the original image followed by quantization of the transformed image coefficients using a quantization matrix which is built experimentally depending on the human visual system that produces a lot of zeros coefficients [6]. Finally the entropy encoding using (Huffman encoding) will be applied on the quantized coefficients.

Lossless compression

HUFFMAN encoding methods. This is a general technique for coding symbols based on their statistical occurrence frequencies (probabilities). The pixels in the image are treated as symbols. The symbols that occur more frequently are assigned a smaller number of bits, while the symbols that occur less frequently are assigned a relatively larger number of bits. Huffman code is a prefix code. This means that the (binary) prefix code of any symbol is different from the binary prefix code of any other symbol. Most image coding standards use lossy techniques in the earlier stages of compression and use Huffman coding as the final step [7].

III. RESULTS AND DISCUSSION

A set of 8 pictures of size 128X128 pixels are used in this research. This dataset is compressed by the wavelet methods (wavelet-bitmap, wavelet-Huffman), measuring the PSNR, compression ratio, and compression time. While calculating the entropy of each input image, the entropy represents a measure of the information contained in the image. The results are shown in table 1 and table 2. Below there is a view of the PSNR, compression ratio and the compression time which are obtained by the wavelet-bitmap method and wavelet-Huffman, respectively.

Table 1. The results of a wavelet-bitmap method

Image name	Wavelet-bitmap Comp. time (min)	PSNR	COMP. RATIO	entropy
Mr11	0.0014599	25.6229	1.5887	6.5305
Mr12	0.0014651	29.9811	1.4907	6.228
Mr13	0.0014373	21.7292	1.413	6.6584
Mr14	0.0014656	27.731	1.6457	7.1785
Mr15	0.0014184	29.725	1.5637	6.2289
Mr16	0.0014409	27.3771	1.9535	4.5778
Mr17	0.0014272	31.3789	2.621	4.1237
Mr18	0.0014403	33.0054	2.3978	4.1551

As it can be seen in figure 1 below which is obtained from the result of table 1 above, the compression process takes short time. Also we note that the change in the time of compression is relatively small. This is because the compression time is mainly image size dependent and it does not depend on the entropy (information and details) of the image. Furthermore, the bit-map process is used to eliminate the zeros coefficients and encode the zeros and non-zeros coefficients and the time of this process is approximately the same in all images because these images are equal in size. The compression ratio will be changed reversely with respect to the entropy but it is not affected by the time of the compression because of the reason mentioned above. Also we expect that the PSNR may change reversely with respect to the entropy and this will be clear if we take more samples of the selected images.

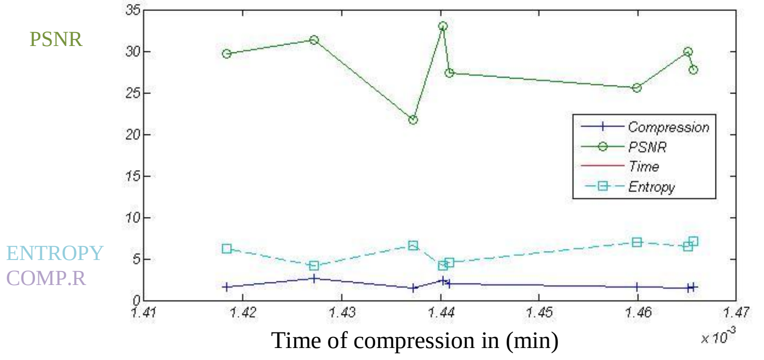

Figure 1. The relation between PSNR, Compression ratio and the entropy vs. time**.**

In the wavelet-Huffman method we have obtained the results shown in the table 2 below:

Table 2. The results of a wavelet-Huffman method

Image name	Wavelet-Huffman Comp. time (min)	PSNR	COMP. RATIO	entropy
Mr11	0.23773	25.63	2.219	7.003
Mr12	0.22379	29.717	2.193	6.5305
Mr13	0.25343	21.7536	2.1058	6.6584
Mr14	0.23149	27.7251	2.1956	7.1785
Mr15	0.2532	29.6493	2.6402	6.2289
Mr16	0.19488	27.3743	2.7384	4.5778
Mr17	0.16906	31.3816	3.1147	4.1237
Mr18	0.16722	32.9898	3.1713	4.1557

It can be seen from figure 2 below which is obtained from the results shown in table 2. The time of the compression of wavelet-Huffman method is longer than the time of the compression that measured for the wavelet-bitmap method, also we note that the change in the time of compression between any two compressed images is relatively high; this is because of the wavelet-Huffman process is more complex than the wavelet-bitmap process. The time of compression in wavelet-Huffman method does not depend only on the size of the image but also depends on the entropy of image. Furthermore, if the image has high entropy, the complexity of the wavelet-Huffman process will increase. This is because the wavelet-Huffman needs to build the tree of the symbols and extract the probability of these symbols. Next, it is necessary to make the binary code of each symbol. These symbols are different from the image to another image depending on the information of it, therefore this process is too complex if it is compared with process of the wavelet-bitmap method because the time of the compression process in the wavelet-Huffman method is a summation of two times;these times are thresholding time and the time taken to build the tree of the symbols. Moreover we see that the compression ratio is affected by the time of the compression for the same reason above. The compression ratio will change reversely with respect to the entropy of the image. It can be seen that the PSNR will change reversely with respect to the entropy of the image.

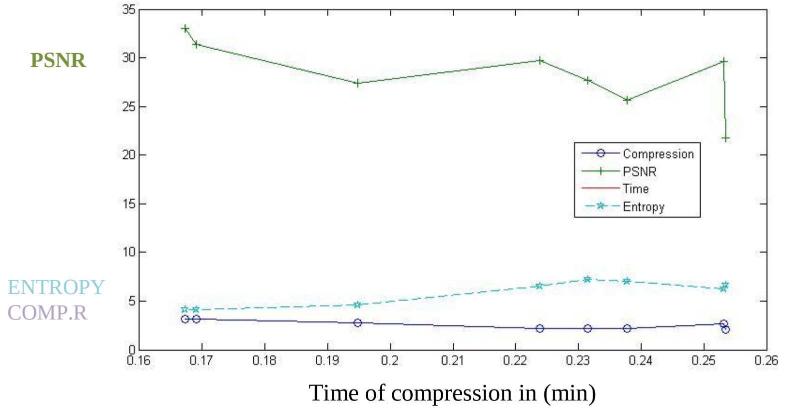

Figure2. The relation of PSNR, compression ratio, and the entropy of the image vs. time.

An experiment was done on transmitting and receiving a digital image between two computers. The transmission time was calculated for different methods of image compression which are mentioned above. This time is compared with the transmission time of the original image shown in the table 3 below:

Table 3. The difference in transmission time between the original image and compressed image

Image name	Type of image	Transmission time(min)
Mr11	Original image	0.25494
Mr11	DCT-huff compressed image	0.04448
Mr11	Wavelet-huff compressed image	.083044
Mr11	Wavelet-bitmap compressed image	0.095401
Mr11	Huffman-compressed image	0.088092

IV. CONCLUSIONS

It is obvious that the compression ratio is changing according to the entropy in both methods (wavelet-Huffman and wavelet-bitmap). When the compression ratio increases, the entropy will decrease. Also the PSNR drops when the compression ratio increased. We can conclude that the PSNR in both methods above is relatively equal and the images that were compressed in both methods have the same quality. The compression ratio resulted from a wavelet-Huffman method is relatively higher than the compression ratio that resulted from a wavelet-bitmap method. This indicates that the wavelet-bitmap is not efficient enough but although the time of compression is reduced. This compression ratio in bit-map method may be modified if another wavelet filter is chosen or the level of the wavelet compression is increased. Also the compression ratio of the wavelet-Huffman method can be enhanced if the zeros coefficients that resulted from the thresholding process is removed.

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