

Image Compression Using Discrete Wavelet Transform

M. Mozammel Hoque Chowdhury and Amina Khatun

Department of Computer Science and Engineering
Jahangirnagar University
Savar, Dhaka-1342, Bangladesh

Abstract

Image compression is a key technology in transmission and storage of digital images because of vast data associated with them. This research suggests a new image compression scheme with pruning proposal based on discrete wavelet transformation (DWT). The effectiveness of the algorithm has been justified over some real images, and the performance of the algorithm has been compared with other common compression standards. The algorithm has been implemented using Visual C++ and tested on a Pentium Core 2 Duo 2.1 GHz PC with 1 GB RAM. Experimental results demonstrate that the proposed technique provides sufficient high compression ratios compared to other compression techniques.

Keywords: *Image compression, DWT, JPEG, GIF, PSNR, MSE, Compression ratio.*

1. Introduction

Image compression is important for many applications that involve huge data storage, transmission and retrieval such as for multimedia, documents, videoconferencing, and medical imaging. Uncompressed images require considerable storage capacity and transmission bandwidth. The objective of image compression technique is to reduce redundancy of the image data in order to be able to store or transmit data in an efficient form. This results in the reduction of file size and allows more images to be stored in a given amount of disk or memory space [1-3].

Image compression can be lossy or lossless [4, 5]. In a lossless compression algorithm, compressed data can be used to recreate an exact replica of the original; no information is lost to the compression process. This type of compression is also known as entropy coding. This name comes from the fact that a compressed signal is generally more random than the original; patterns are removed when a signal is compressed. While lossless compression is useful for exact reconstruction, it generally does not provide sufficiently high compression ratios to be truly useful in image compression. Lossless image compression is particularly useful in image archiving as in

the storage of legal or medical records. Methods for lossless image compression includes: Entropy coding, Huffman coding, Bit-plane coding, Run-length coding and LZW (Lempel Ziv Welch) coding.

In lossy compression, the original signal cannot be exactly reconstructed from the compressed data. The reason is that, much of the detail in an image can be discarded without greatly changing the appearance of the image. As an example consider an image of a tree, which occupies several hundred megabytes. In lossy image compression, though very fine details of the images are lost, but image size is drastically reduced. Lossy image compressions are useful in applications such as broadcast television, videoconferencing, and facsimile transmission, in which a certain amount of error is an acceptable trade-off for increased compression performance. Methods for lossy compression include: Fractal compression, Transform coding, Fourier-related transform, DCT (Discrete Cosine Transform) and Wavelet transform.

In this research a new and very competent image compression scheme is proposed based on discrete wavelet transform that results less computational complexity with no sacrifice in image quality. The performance of the proposed algorithm has been compared with some other common compression standards. Several quality measurement variables like peak signal to noise ratio (PSNR) and mean square error (MSE) have been estimated to determine how well an image is reproduced with respect to the reference image.

This article is structured as follows: Section 2 describes the basic principles of image compression technique, Section 3 illustrates the fundamentals of wavelet transform, Section 4 presents the proposed method using discrete wavelet transform, Section 5 demonstrates the experimental results and discussions. Finally, Section 6 concludes the paper.

2. Image Compression and Reconstruction

Fig. 1 shows the basic steps in an image compression system. The image compression system is composed of two distinct structural blocks: an encoder and a decoder. Image $f(x,y)$ is fed into the encoder, which creates a set of symbols from the input data and uses them to represent the image. Image $\hat{f}(x,y)$ denotes an approximation of the input image that results from compressing and subsequently decompressing the input image.

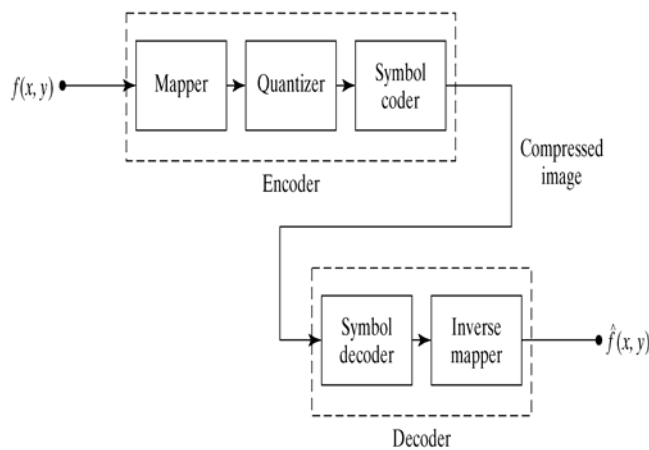


Fig. 1 Basic steps in an image compression system.

The compression that is achieved can be quantified by the compression ratio given by the following formula:

$$C_R = n_1/n_2 \quad (1)$$

where n_1 and n_2 denote the number of information carrying units (bits) in the original image and the compressed image respectively. A compression ratio like 10 (or 10:1) indicates that the original image has 10 information carrying units (e.g. bits) for every 1 unit in the compressed data set.

Several quality measurement variables like, PSNR (peak signal-to-noise ratio), MSE (mean square error) etc. can be measured to find out how well an image is reproduced with respect to the reference image. These variables are signal fidelity metrics and do not measure how viewers perceive impairments. Numerical values of these variables for any image tell us about the quality of that image [6-8]. The measure of peak signal-to-noise ratio (PSNR) is defined as the following formula:

$$PSNR = 10 \log_{10}(255^2 / MSE) \text{ dB} \quad (2)$$

and, mean square error (MSE) is given by,

$$MSE = \frac{1}{MN} \sum_{x=1}^M \sum_{y=1}^N [f(x,y) - \hat{f}(x,y)]^2 \quad (3)$$

3. The Wavelet Transform

Wavelets are signals which are local in time and scale and generally have an irregular shape. A wavelet is a waveform of effectively limited duration that has an average value of zero. The term ‘wavelet’ comes from the fact that they integrate to zero; they wave up and down across the axis. Many wavelets also display a property ideal for compact signal representation: orthogonality. This property ensures that data is not over represented. A signal can be decomposed into many shifted and scaled representations of the original mother wavelet. A wavelet transform can be used to decompose a signal into component wavelets. Once this is done the coefficients of the wavelets can be decimated to remove some of the details. Wavelets have the great advantage of being able to separate the fine details in a signal. Very small wavelets can be used to isolate very fine details in a signal, while very large wavelets can identify coarse details. In addition, there are many different wavelets to choose from. Various types of wavelets are: Morlet, Daubechies, etc. [9, 10]. One particular wavelet may generate a more sparse representation of a signal than another, so different kinds of wavelets must be examined to see which is most suited to image compression.

A wavelet function $\Psi(t)$ has two main properties,

$$\int_{-\infty}^0 \Psi(t) dt = 0;$$

That is, the function is oscillatory or has wavy appearance.

$$\int_{-\infty}^0 |\Psi(t)|^2 dt < \infty;$$

That is, the most of the energy in $\Psi(t)$ is confined to a finite duration.

4. Proposed Compression Method using DWT

This section illustrates the proposed compression technique with pruning proposal based on discrete wavelet transform (DWT). The proposed technique first decomposes an image into coefficients called sub-bands and then the resulting coefficients are compared with a

threshold. Coefficients below the threshold are set to zero. Finally, the coefficients above the threshold value are encoded with a loss less compression technique.

The compression features of a given wavelet basis are primarily linked to the relative scarceness of the wavelet domain representation for the signal. The notion behind compression is based on the concept that the regular signal component can be accurately approximated using the following elements: a small number of approximation coefficients (at a suitably chosen level) and some of the detail coefficients.

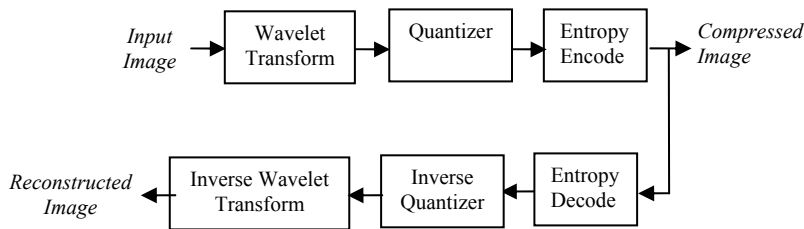


Fig. 2 The structure of the wavelet transform based compression.

The steps of the proposed compression algorithm based on DWT are described below:

I. Decompose

Choose a wavelet; choose a level N. Compute the wavelet. Decompose the signals at level N.

II. Threshold detail coefficients

For each level from 1 to N, a threshold is selected and hard thresholding is applied to the detail coefficients.

III. Reconstruct

Compute wavelet reconstruction using the original approximation coefficients of level N and the modified detail coefficients of levels from 1 to N.

5. Experimental Results and Discussion

In this research, an efficient compression technique based on discrete wavelet transform (DWT) is proposed and developed. The algorithm has been implemented using Visual C++. A set of test images (bmp format) are taken to justify the effectiveness of the algorithm. **Fig. 3** shows a test image and resulting compressed images using JPEG, GIF and the proposed compression methods.

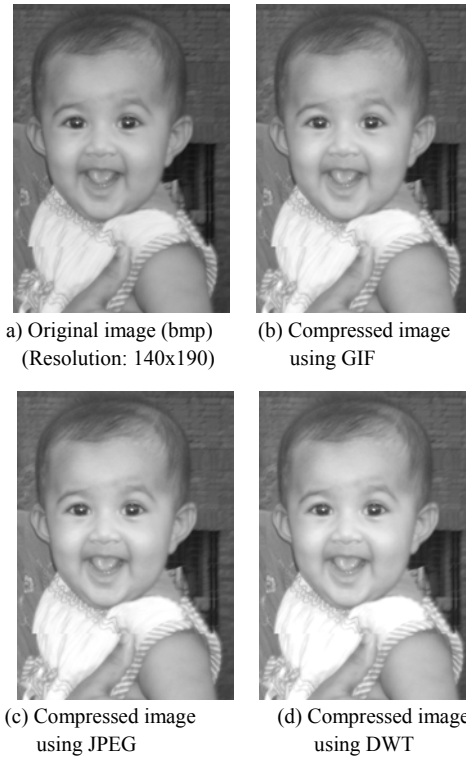


Fig.3 A real image and corresponding compressed images with GIF, JPEG and proposed DWT methods.

The experimental results with the proposed compression method have been arranged in the **Table 1** for different threshold values. From this table, we find that a threshold value of $\delta = 30$ is a good choice on the basis of trade-off for different compression ratios. **Table 2** shows the comparison between JPEG, GIF and the proposed compression method. Experimental results demonstrate that the proposed compression technique gives better performance compared to other compression techniques.

Table 1. Compression Results with Proposed Method for different threshold values

Threshold values	Size of the original image	Size of the compressed image with DWT	Compression Ratio
Without Threshold	47 KB	2.38 KB	19.74:1
$\delta=10$	47 KB	2.16 KB	21.75:1
$\delta=20$	47 KB	2.10 KB	22.38:1
$\delta=30$	47 KB	1.94 KB	24.22:1
$\delta=40$	47 KB	2.14 KB	21.96:1
$\delta=50$	47 KB	2.12 KB	22.16:1

Table 2. Comparison between DWT and other Compression methods

Compression Techniques	File sizes	Compression Ratio	PSNR (dB)
Original Image(Bmp)	47.00 KB	-	-
GIF	6.40 KB	7.34:1	27.37
JPEG	3.38 KB	13.90:1	24.42
DWT (Proposed Method)	1.94 KB	24.22:1	19.86

6. Conclusions

A new image compression scheme based on discrete wavelet transform is proposed in this research which provides sufficient high compression ratios with no appreciable degradation of image quality. The effectiveness and robustness of this approach has been justified using a set of real images. The images are taken with a digital camera (OLYMPUS LI-40C). To demonstrate the performance of the proposed method, a comparison between the proposed technique and other common compression techniques has been revealed. From the experimental results it is evident that, the proposed compression technique gives better performance compared to other traditional techniques. Wavelets are better suited to time-limited data and wavelet based compression technique maintains better image quality by reducing errors. The future direction of this research is to implement a compression technique using neural network.

References

[1] S. Bhavani, K. Thanushkodi, "A Survey on Coding Algorithms in Medical Image Compression", International Journal on Computer Science and Engineering, Vol. 02, No. 05, pp. 1429-1434, 2010.
 [2] G. K. Kharate, V. H. Pati, "Color Image Compression Based On Wavelet Packet Best Tree", International Journal of Computer Science, Vol. 7, No.3, March 2010.
 [3] M. R. Haque and F. Ahmed, "Image data compression with JPEG and JPEG2000", 8th International Conference on Computer and Information Technology, pp. 1064-1069, 2005.

[4] M. J. Weinberger, G. Seroussi and G. Sapiro, "The LOCO-I lossless image compression algorithm: Principles and standardization into JPEG-LS", IEEE Trans. on Image Processing, Vol. 2, pp. 1309-1324, Aug. 2000.
 [5] Madhuri A. Joshi, "Digital Image Processing, An Algorithmic Approach", PHI, New Delhi, pp. 175-217, 2006.
 [6] C. M. Rahman and A. Y. Saber, "Image compression using dynamic clustering and neural network", 5th International Conference on Computer and Information Technology, pp. 453-458, December 2002.
 [7] N. A. Koli, M. S. Ali, "A Survey on Fractal Image Compression Key Issues", Information Technology Journal, 2008.
 [8] L. Bottou, P. G. Howard, and Y. Bengio, "The Z-Coder Adaptive Binary Coder, Proc. IEEE DCC, pp. 13-22, Mar. 1998.
 [9] Othman Khalifa, "Wavelet Coding Design for Image Data Compression", The International Arab Journal of Information Technology, Vol. 6, No. 2, pp. 118-127, April 2009
 [10] A. Alice Blessie1, J. Nalini and S.C.Ramesh, "Image Compression Using Wavelet Transform Based on the Lifting Scheme and its Implementation", IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 1, May 2011.

M. Mozammel Hoque Chowdhury is working as an Associate Professor in the Department of Computer Science and Engineering, Jahangirnagar University, Savar, Dhaka, Bangladesh. He received his B.Sc. (Honors) degree in Electronics and Computer Science and MS degree in Computer Science and Engineering from the same university. He has published more than 25 articles in international and national journals and conference proceedings. His research interest includes: Image Processing, Computer Vision, Machine Intelligence, E-learning and E-governance.

Amina Khatun is working as a Lecturer in the Department of Computer Science and Engineering, Jahangirnagar University, Savar, Dhaka, Bangladesh. She obtained her B.Sc. (Honors) in Computer Science & Engineering from Jahangirnagar University and MS degree in Computer Science from North South University, Bangladesh. Her research interest includes: Image Processing, Computer Vision, Artificial Intelligence and so on.