Image Compression Implementation using Discrete Wavelet Transform

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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.

Key words: Image Compression, DWT, JPEG, GIF, PSNR, MSE, Compression Ratio

I. Introduction

Image compression may be lossy or lossless. Lossless compression is preferred for archival purposes and often for medical imaging, technical drawings, clip art, or comics. Lossy compression methods, especially when used at low bit rates, introduce compression artifacts. Lossy methods are especially suitable for natural images such as photographs in applications where minor (sometimes imperceptible) loss of fidelity is acceptable to achieve a substantial reduction in bit rate. Lossy compression that produces negligible differences may be called visually lossless.

A. *Methods For Lossless Image Compression Are*

- Run-length encoding – used in default method in PCX and as one of possible in BMP, TGA, TIFF
- Area image compression
- DPCM and Predictive Coding
- Entropy encoding
- Adaptive dictionary algorithms such as LZW – used in GIF and TIFF
- Deflation – used in PNG, MNG, and TIFF
- Chain codes

B. *Methods for Lossy Compression*

Reducing the color space to the most common colors in the image. The selected colors are specified in the colour palette in the header of the compressed image. Each pixel just references the index of a color in the color palette, this method can be combined with dithering to avoid posterization.

C. *Chroma Subsampling*

This takes advantage of the fact that the human eye perceives spatial changes of brightness more sharply than those of color, by averaging or dropping some of the chrominance information in the image.

Transform coding. This is the most commonly used method. In particular, a Fourier-related transform such as the Discrete Cosine Transform (DCT) is widely used.

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. In Information technology, lossy compression or irreversible compression is the class of data encoding methods that uses inexact approximations and partial data discarding to represent the content. These techniques are used to reduce data size for storage, handling, and transmitting content. Different versions of the photo of the cat above show how

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higher degrees of approximation create coarser images as more details are removed. This is opposed to lossless data compression (reversible data compression) which does not degrade the data. The amount of data reduction possible using lossy compression is much higher than through lossless techniques. Well-designed lossy compression technology often reduces file sizes significantly before Lossy compression is most commonly used to compress multimedia data (audio, video, and images), especially in applications such as streaming media and internet telephony. By contrast, lossless compression is typically required for text and data files, such as bank records and text articles.

In many cases it is advantageous to make a master lossless file which is to be used to produce new compressed files; for example, a multi-megabyte file can be used at full size to produce a full-page advertisement in a glossy magazine, and a 10 kilobyte lossy copy can be made for a small image on a web page.

Lossless compression is a class of data compression algorithms that allows the original data to be perfectly reconstructed from the compressed data. By contrast, lossy compression permits reconstruction only of an approximation of the original data, though this usually improves compression rates (and therefore reduces file sizes). Lossless data compression is used in many applications. For example, it is used in the ZIP file format and in the GNU tool gzip. It is also often used as a component within lossy data compression technologies (e.g. lossless mid/side joint stereo preprocessing by MP3 encoders and other lossy audio encoders).

Lossless compression is used in cases where it is important that the original and the decompressed data be identical, or where deviations from the original data would be unfavorable. Typical examples are executable programs, text documents, and source code. Some image file formats, like PNG or GIF, use only lossless compression, while others like TIFF and MNG may use either lossless or lossy methods. Lossless audio formats are most often used for archiving or production purposes, while smaller lossy audio files are typically used on portable players and in other cases where storage space is limited or exact replication of the audio is unnecessary. Transform coding is a type of data compression for "natural" data like audio signals or photographic images. The transformation is typically lossless (perfectly reversible) on its own but is used to enable better (more targeted) quantization, which then results in a lower quality copy of the original input (lossy compression).

In transform coding, knowledge of the application is used to choose information to discard, thereby lowering its bandwidth. The remaining information can then be compressed via a variety of methods. When the output is decoded, the result may not be identical to the original input, but is expected to be close enough for the purpose of the application.

II. 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.

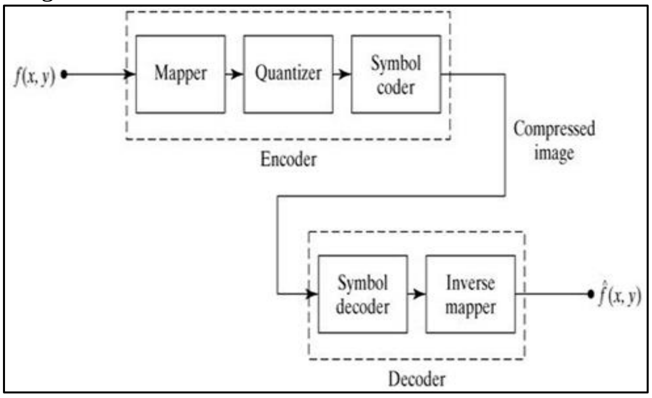


Fig. 1: Basic Steps in an Image Compression System

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

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

III. 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 Ψ(t) has two main properties,

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

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

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

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

– 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(2) 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.

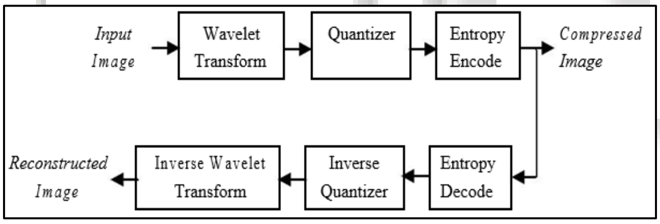


Fig. 2: The Structure of the Wavelet Transform Based Compression.

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

A. *Decompose*

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

B. *Threshold Detail Coefficients*

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

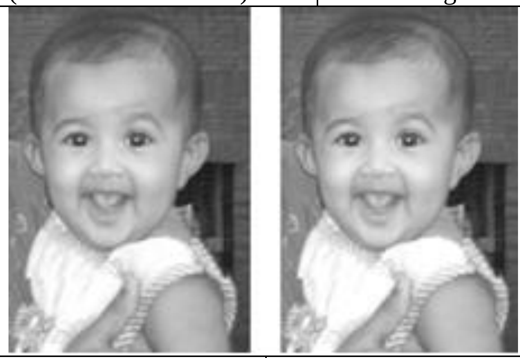
C. *Reconstruct*

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

IV. 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.

(a) Original Image (bmp) (Resolution: 140x190)	(b) Compressed Image using GIF



(c) Compressed Image Using JPEG	(d) Compressed Image Using DWT

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 δ = 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.

Threshold Without Threshold	Size of the original image	Size of the	Compression
δ=10	47 KB	2.16 KB	21.75:1
δ=20	47 KB	2.10 KB	22.38:1
δ=30	47 KB	1.94 KB	24.22:1
δ=40	47 KB	2.14 KB	21.96:1

Table 1: Compression Results with Proposed Method for Different Threshold Values

Compression Techniques	File sizes	Compression Ratio	PSNR (dB)
Original	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

Table 2: Comparison between DWT and Other Compression Methods

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V. 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.

VI. FUTURE SCOPE

The future direction of this research is to implement a compression technique using neural network.

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