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Implementation of Image Compression Using Hybrid DWT - DCT Algorithms

G. BUELA DIVYA[1] , M. KRUPA SWAROOPA RANI.
[1]Student M.Tech (ECE),Sri Padmavati Mahila University, Tirupathi,
[2]Lecturer/Department of ECE,Sri Padmavati Mahila University, Tirupathi,

Abstract - This paper describes architecture of DCT and DWT standard of an image compression. It is used specially for the compression of images where tolerable degradation is required. The discrete cosine transform is a fast transform and has fixed basis images which gives good compromise between information packing ability and computational complexity. DWT can be used to reduce the image size without losing much of the resolutions computed and values less than a pre-specified threshold. This paper covers some background of wavelet analysis, data compression and how DCT and DWT can be used for image compression and we propose a hybrid DWT-DCT algorithm for image compression and reconstruction taking benefit from the advantages of both algorithms. The algorithm performs the Discrete Cosine Transform (DCT) on the Discrete Wavelet Transform (DWT) coefficients.

Index Terms — Discrete wavelet transform (DWT), image compression, wavelets, Discrete cosine transform (DCT), hybrid DWT-DCT.

I. INTRODUCTION

Image compression is very important for efficient transmission and storage of images. Images contain large amounts of information that requires much storage space, large transmission bandwidths and long transmission times. Therefore, it is advantageous to compress the image by storing only the essential information needed to reconstruct the image. An image can be thought of as a matrix of pixel (or intensity) values. Image compression standards bring about many benefits, such as: (1) easier exchange of image files between different devices and applications; (2) reuse of existing hardware and software for a wider array of products; (3) existence of benchmarks and reference data sets for new and alternative developments. Digital image compression techniques can be divided into two classes: lossless and lossy compression. In lossless compression schemes, the reconstructed image, after compression, is numerically identical to the original image. Lossless image compression is particularly useful in applications such as image archiving (as in the storage of legal or medical records) and facsimile transmission. However, most of the applications today use lossy image compression because of its higher compression ratio compared with lossless image compression.

The DCT process is applied on blocks of 8 * 8 or 16 * 16 pixels, which will convert into series of coefficients, which define spectral composition of the block. The Transformer transforms the input data into a format to reduce inter pixel redundancies in the input image. Transform coding techniques use a reversible, linear mathematical transform to map the pixel values onto a set of coefficients, which are then quantized and encoded. The key factor behind the success of transform-based coding schemes is that many of the resulting coefficients for most natural images have small magnitudes and can be quantized without causing significant distortion in the decoded image. For compression purpose, the higher the capability of compressing information in fewer coefficients, the better the transform; for that reason, the Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) have become the most widely used transform coding techniques. The 2-D DCT is a separable transform consisting of Forward Discrete Cosine Transform (FDCT) and Inverse Discrete Cosine Transform (IDCT).

In the next section, we mainly concentrate on discussing the background information required for understanding this research topic. The image compression basics are described in Section II. In Section III, describes the methodologies used in image compression. In Section IV, experimental result. The final section includes conclusion.

II. IMAGE COMPRESSION BASICS

The neighboring pixels of most natural images are highly correlated and thus contain lot of redundant information. A less correlated representation of the image is the result of any compression algorithm. The main task of image compression algorithms is reduction of redundant and irrelevant information. In the present scenario, various methods of compressing still images exist. In any data compression scheme, three basic steps are involved: Transformation, Quantization and Encoding. The basic block diagram of an image compression system is shown in Figure 1.

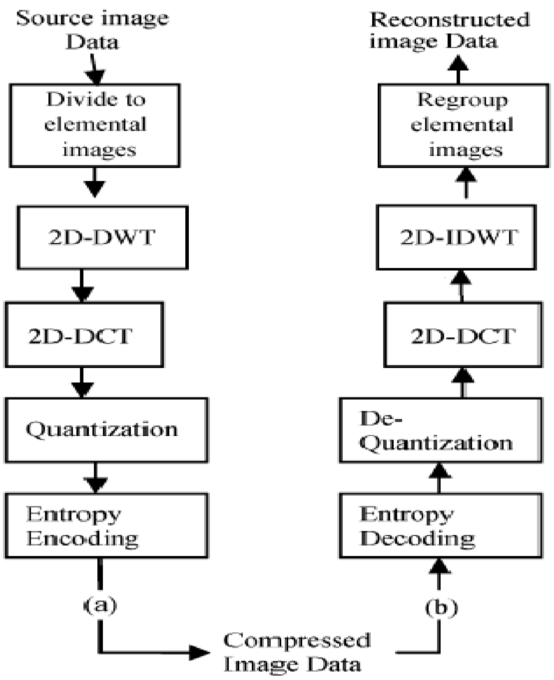

Fig. 1. Outline of the image compression process.

1. Transformation

In image compression, transform is indented to de-correlate the input pixels. Selection of proper transform is one of the important issues in image compression schemes. The transform should be selected in such a way that it reduces the size of the resultant data set as compared to the source data set. Few transformations reduce the numerical size of the data items that allow them to represent by fewer binary bits. The technical name given to these methods of transformation is mapping. Some mathematical transformations have been invented for the sole purpose of data compression; others have been borrowed from various applications and applied to data compression. These include the Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) [4], Walsh-Hadamard Transform (WHT), Hadamard-Haar Transform (HHT), Karhune-Loeve Transforms (KLT), Slant-Haar Transform (SHT), Short Fourier Transforms (SFT), and Wavelet Transforms (WT) [3]. Transform selection process still remains an active field of research.

2. Quantization

The procedure of approximating the continuous set of values in the image data with a finite, preferably small set of values is called quantization. The original data is the input to a quantizer and the output is always one among a limited number of levels. The quantization step may also be followed by the process of thresholding. Each sample is scaled by a quantization factor in the process of quantization, whereas the samples are eliminated if the value of the sample is less than the defined threshold value, in the process of thresholding. These two methods are responsible for the introduction of error and leads to degradation of quality. The degradation is based on selection of quantization factor and the value of threshold. If the threshold value is high, the loss of information is more, and vice versa. The value of threshold or the quantization factor should be selected in a way that it satisfies the constraints of human visual system for better visual quality at high compression ratios. Quantization is a process of approximation. A good quantizer is the one which represents the original signal with minimum distortion. If lossless compression is desired this step should be eliminated.

3. Encoding

Encoding process reduces the overall number of bits required to represent the image. An entropy encoder compresses the quantized values further to give better overall compression. This process removes the redundancy in the form of repetitive bit patterns at the output of the quantizer. It uses a model to precisely determine the probabilities for each quantized value and produces a suitable code based on these probabilities so that the resultant output code stream will be smaller than the input. Commonly used entropy coders are the Huffman encoder and the Arithmetic encoder. The Huffman procedure needs each code to have an integral number of bits, while arithmetic coding techniques allow for fractional number of bits per code by grouping two or more similar codes together into a block composed of an integral number of bits. This makes arithmetic codes to perform better than Huffman codes. Therefore, arithmetic codes are more commonly used in wavelet based algorithms. The decoding process involves the reverse operation of the encoding steps with the exception of de-quantization step that cannot be reversed exactly.

3.1 Arithmetic Coding

This is one of the latest and popular encoding schemes. In arithmetic coding, symbols are restricted in such a way that translation is done into an integral number of bits, thus making the coding more efficient. In this coding, the data is represented by an interval of real numbers between 0 and 1. As the data becomes larger, the interval required for representation becomes smaller, and the number of bits required specifying that interval increases. Successive symbols of the data reduce the size of the interval according to the probabilities of the symbol generated by the model. The data that is more likely has more reduced ranged compared to the unlikely data, thus fewer bits are used. The above mentioned entropy encoding schemes are chosen in application in wavelet image compression with the preference of coding simplicity, effectiveness in minimization of entropy and the lossless compression ratio.

III. METHODOLOGIES USED FOR IMAGE COMPESSION

A. DISCRETE COSINE TRANSFORM (DCT)

DCT Attempts to decorrelate the image data after decorrelation each transform coefficient can be encoded without dropping off compression efficiency. The DCT and some of its important properties. The DCT for an N×N input sequence can be defined as where x=0, 1, ….., n-1, is the list of length n given by:

$$D_{DCT}(i,j) = \frac{1}{\sqrt{2N}} B(i)B(j) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} M(x,y)$$
$$.\cos\left[\frac{(2x+1)}{2N} i\pi\right] \cos\left[\frac{(2y+1)}{2N} j\pi\right]$$

Where

$$B(u) = \begin{cases} \frac{1}{\sqrt{2}} & if \quad u = 0 \\ 1 & if \quad u > 0 \end{cases}$$

For u= 0, 1, 2, … N-1.

N is the size of the block that the DCT is applied on. The equation calculates one entry (i, jth) of the transformed image from the pixel values of the original image matrix.

M(x,y) is the original data of size x* y.

B. DISCRETE WAVELET TRANSFORM (DWT)

The DWT represents an image as a sum of wavelet functions, known as wavelets, with different location and scale. The DWT represents the image data into a set of high pass (detail) and low pass (approximate) coefficients. The image is first divided into blocks of 32×32. Each block is then passed through the two filters: the first level decomposition is performed to decompose the input data into an approximation and detail coefficients. After obtaining the transformed matrix, the detail and approximate coefficients are separated as LL,HL, LH, and HH coefficients. All the coefficients are discarded except the LL coefficients that are transformed into the second level. The coefficients are then passed through a constant scaling factor to achieve the desired compression ratio.

An illustration is shown in Fig. 2. Here, x[n] is the input signal, d[n] is the high frequency component, and a[n] is the low frequency component. For data reconstruction, the coefficients are rescaled and padded with zeros, and passed through the wavelet filters.

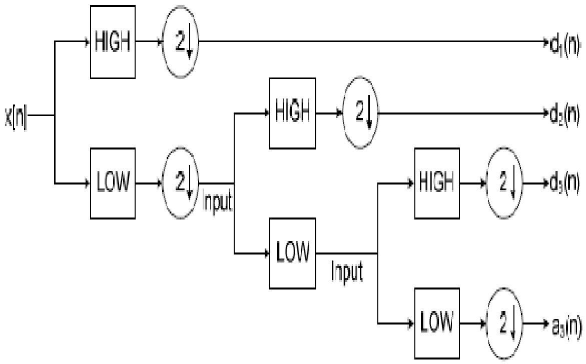

Fig. 2 Block diagram of the 2-level DWT scheme

3 PROPOSED HYBRID DWT- DCT ALGORITHMS:

The main objective of the presented hybrid DWT-DCT algorithm is to exploit the properties of both the DWT and the DCT. Giving consideration of the type of application, original image/frame of size 256×256 (or any resolution, provided divisible by 32) is first divided into blocks of N×N. Each block is then decomposed using the 2-D DWT. (9) Low-frequency coefficients (LL) are passed to the next stage where the high frequency coefficients (HL, LH, and HH) are discarded.

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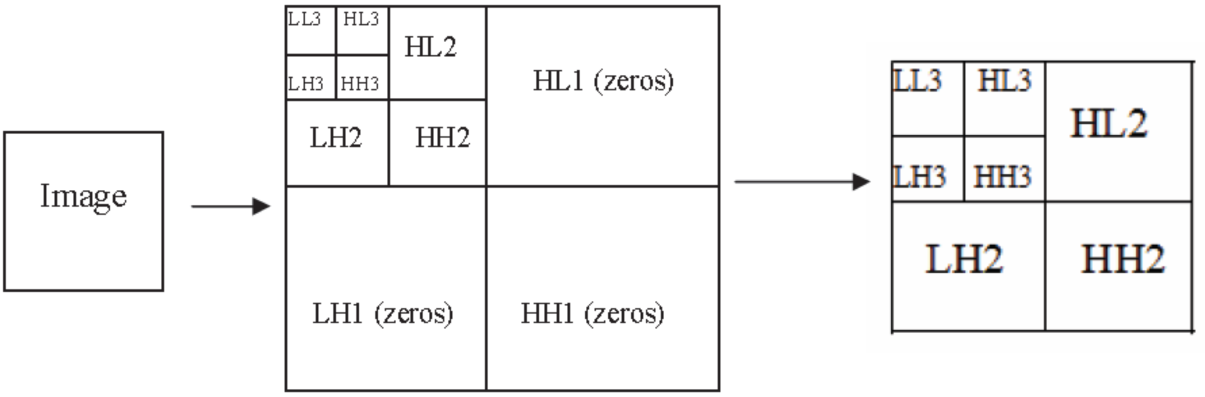
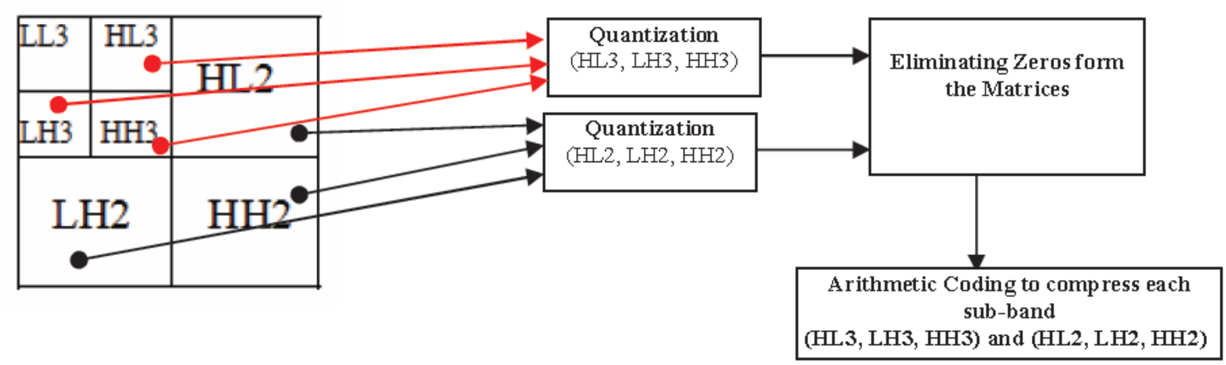
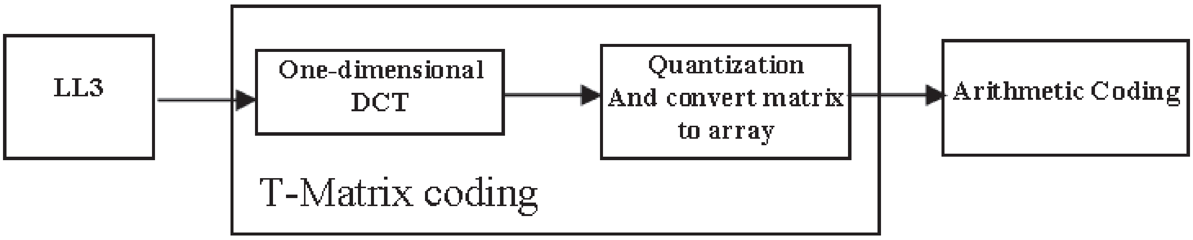


a) First step; Transform image by using three level Discrete Wavelet Transform



b) Second step; quantization and eliminate zeros form each sub-band, and then compress each sub-band by Arithmetic Coding



c) Third step; compress LL3 sub-band by using T-Matrix Coding.

Fig 3 - (a, b, c), complete steps for Hybrid DWT- DCT algorithms

The passed LL components are further decomposed using another 2-D DWT. The 8-point DCT is applied to these DWT coefficients. By discarding the majority of the high coefficients, we can achieve a high compression. To achieve further compression, a JPEG-like quantization is performed. In this stage, many of the higher frequency components are rounded to zero. The quantized coefficients are further scaled using scalar quantity known as scaling factor (SF).Each sub-band is to be quantized and the obtained zeros are to be eliminated. On applying1-D DCT to each sub-band, it is converted to array by using quantization. This process is called T-MATRIX coding. This code is converted to binary data by Arithmetic coding.
Finally, the image is reconstructed following the inverse procedure.

IV. EXPERIMENTAL RESULT

In this section, the performance of the algorithms using two popular measures: compression ratio (CR) and peak signal to noise ratio (PSNR) has been analyzed. Mean Square error (MSE) Image having same PSNR value may have different perceptual quality.

1. Peak Signal-to-Noise Ratio (PSNR):

PSNR is usually expressed in terms of the logarithmic decibel scale. The PSNR is most commonly used as a measure of quality of reconstruction in image compression etc.

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

2. Compression ratio (CR):

The compression ratio is defined as follows: The resulting CR can be varied according to the image quality and the level of compression.

$$CR = \frac{Discarded \quad data}{Original \quad data}$$

3. Mean Square Error (MSE):

MSE is called squared error loss. MSE measures the average of the square of the "error". The MSE is the second moment (about the origin) of the error, and thus incorporates both the variance of the estimator and its bias.

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

Table 1 Compression Results with Proposed Method

size of original image (Kb)	size of compressed image (Kb)	Compression ratio	PSNR	MSE
1341.44	62.50	21.46	33.62	28.49
732	35.20	20.80	35.27	19.61
768	37.90	20.26	39.28	8.04
2017.28	102	19.78	35.62	18.00

V. CONCLUSION

In this paper, we present a new hybrid scheme combing the DWT and the DCT algorithms under high compression ratio constraint. The algorithm performs the DCT on the lowest level DWT coefficient. DCT takes advantage of redundancies of the data by grouping pixels with similar frequencies. This paper has concentrated on development of efficient and effective algorithm for still image compression. The results of this exhaustive simulation show consistent improved performance for the hybrid scheme compared to the JPEG-based DCT and the Daubechies-based DWT . The new scheme performs better in a noisy environment and reduces the false contouring effects and blocking artifacts significantly. The analysis shows that for a fixed level of distortion, the number of bits required to transmit the hybrid coefficients would be less than those required for other schemes. Our future work involves improving image quality by increasing PSNR value and lowering MSE value.

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