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RESEARCH ARTICLE

Hybrid Compression Using DWT-DCT and Huffman Encoding Techniques for Biomedical Image and Video Applications

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Abstract— Digital image and video in their raw form require an enormous amount of storage capacity. Considering the important role played by digital imaging and video, it is necessary to develop a system that produces high degree of compression while preserving critical image/video information. There is various transformation techniques used for data compression. Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are the most commonly used transformation. DCT has high energy compaction property and requires less computational resources. On the other hand, DWT is multi resolution transformation. In this work, we propose a hybrid DWT-DCT, Huffman algorithm for image and video 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. Simulations have been conducted on several natural, benchmarks, medical and endoscopic images. Several high definition and endoscopic videos have also been used to demonstrate the advantage of the proposed scheme. Huffman coding is used to encode the compressed bit streams at compression stage. In reconstruction stage, it is used to decode the received encoded bit streams. It also increases the compression ratio.

Key Terms: - Biomedical images and videos; Compression ratio (CR); DCT; DWT; Huffman coding; PSNR; SSIM

I. INTRODUCTION

The Data compression is one of the major areas of the research in image and video processing applications. With the development of computer and internet technology, more multimedia-based information is being transmitted over the internet and wireless networks. The raw data to be transmitted consumes large bandwidth and requires huge storage space; as a result, it is desirable to represent the information in the data with considerably fewer bits by the mean of data compression techniques. At a same time, the data compression technique must be able to reconstruct the data very close to original data. This can be achieved via an effective and efficient compression and decompression algorithms.

The DCT and DWT are the most commonly used algorithms. The DCT has high energy compaction property and requires less computational resources. The energy compaction property of an algorithm refers to the ability to concentrate most important information signal into as much as few low frequency component. On the other hand, DWT is a multi-resolution transform and variable compression can be easily achieved. The main disadvantages of DCT are introduction of false contouring effects and blocking artifacts at higher compression,

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and, that of DWT is requirement of large computational resources. So, the idea of exploring the advantages of both algorithms motivated us to investigate combination of DWT and DCT algorithms. Such combination of two algorithms is referred as '*hybrid'* algorithm.

In this research work, we present a hybrid algorithm [1], [2], [3]: 2-level 2-D DWT followed by (8 x 8) 2-D DCT and Huffman coding. The 2-D DWT will be applied on 32 x 32 data block of an image. The main advantage of applying two stage of DWT is to achieve high compression while maintain reconstruction quality. Huffman coding increases the compression ratio. The main objective of this research work is to investigate the performance of proposed hybrid algorithm for wide range of image and video applications at various compression levels.

II. TRANSFORM TECHNIQUES FOR IMAGE/VIDEO COMPRESSION

The various methods of transformations being used for data compression as follows:

A. Discrete Cosine Transform (DCT)

The performance of DCT is very close to the Karhunen-Loeve Transform (KLT) and requires less computational complexity [4]. In addition, DCT has property of higher energy compaction compared to DFT, DST, WHT and DWT. Hence, DCT is generally used for image and video compression. However, for the higher compression, it introduces blocking artifacts and the contour effects in reconstructed image. Besides that, it is not the multi-resolution transformation technique. The 2-D DCT for an *N* x *N* input sequence can be defined as follows:

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

The de-quantized matrix is then transformed back using the 2-D inverse-DCT. The equation for the 2- D inverse DCT transform is given in the equation (2).

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

Limitations of DCT: For higher compression ratio DCT has following two limitations.

1) *Blocking artifacts*: Blocking artifacts is a distortion that appears due to heavy compression and appears as abnormally large pixel blocks. For the higher compression ratio, the noticeable "blocking artifacts" across the block boundaries cannot be neglected.

2) *False contouring:* The false contouring occurs when smoothly graded area of an image is distorted by an aberration that looks like a contour map for specific images having gradually shaded areas. The main cause of the false contouring effect is the heavy quantization of the transform coefficients.

B. Discrete Wavelet Transform (DWT)

DWT is multi-resolution transform technique, generally used for image and video compression to achieve higher compression ratio. Multiple transformation methods can be used in order to compensate the drawbacks of each other. In case of 2-D DWT, the input data is passed through set of both low pass and high pass filter in two directions, both rows and columns. The outputs are then down sampled by 2 in each direction as in case of 1-D DWT. The complete process is illustrated in Fig.1. As shown in Fig.1, output is obtained in set of four coefficients LL, HL, LH and HH. The first alphabet represents the transform in row whereas the second alphabet represents transform in column. The alphabet L means low pass signal and H means high pass signal. LH signal is a low pass signal in row and a high pass in column. Hence, LH signal contain horizontal elements. Similarly, HL and HH contains vertical and diagonal elements, respectively. In DWT reconstruction, input data can be achieved in multiple resolutions [5] by decomposing the LL coefficient further for different levels as shown in Fig.2. In order to reconstruct the output data, the compressed data is up-sampled by a factor of 2. The signal is further passed through the same set of high pass and low pass filter in both rows and columns.

C. Huffman Coding

Huffman coding is a statistical lossless data compression technique. Huffman coding is based on the frequency of pixel in images. It helps to represent a string of symbols with lesser number of bits. In this lossless compression shorter codes are assigned to the most frequently used symbols, and longer codes to the symbols

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which appear less frequently in the string. This algorithm is an optimal compression algorithm when only the frequencies of individual letters are used to compress the data. Therefore, Huffman coding when combined with technique of reducing the image redundancies using Discrete Cosine Transform (DCT) helps in compressing the image data to a better level.

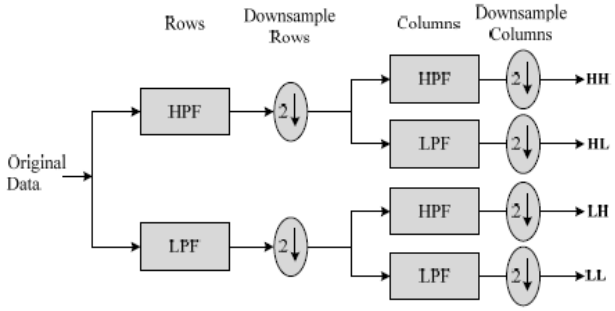

Fig.1 Block diagram of 2-D forward DWT

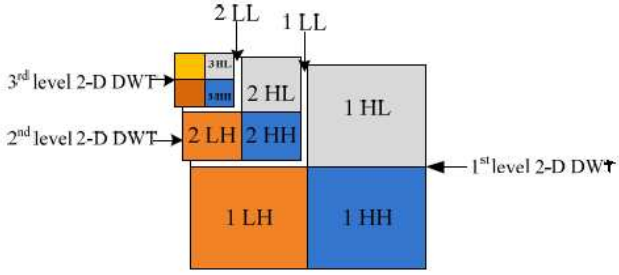

Fig.2 Illustration of forward DWT

III. HYBRID DWT-DCT, HUFFMAN ALGORITHM

The medical image of any size that can be divisible by 32 is considered for the analysis. The image is divided into 32 x 32 blocks and the entire hybrid DWT-DCT algorithm was implemented. The analysis shows that proposed hybrid DWT-DCT algorithm has better performance as compared to stand alone DWT and DCT in terms of Peak Signal to Noise Ratio (*PSNR*), Structural Similarity index (SSIM) and Compression Ratio (*CR*).

A. The process of data compression

Given consideration of the type of application, the original image/frame of size 256 x 256 (or any resolution, provided divisible by 32) is first divided into blocks of size 32 x 32. Each 32 x 32 block is then decomposed using the 2-D DWT. The high-frequency coefficients HL, LH, and HH are discarded. At this level, 75% of data are compressed. The low frequency coefficients (LL) are passed to the next stage. The passed LL components are further decomposed using 2-D DWT. The compression level can be adjusted by applying various DWT sub sampling methods. The concepts of DWT sub sampling is pictorially explained in Fig.3. Fig. 3(a) shows the fully sampled DWT sub sampling, (b) shows the quarterly sampled DWT sub sampling and (c) shows the half sampled DWT sub sampling.

1) *Fully sampled DWT sub sampling:* In this method of DWT sub sampling, all the LL, HL, LH, and HH coefficients are taken into consideration.
2) *Quarterly sampled DWT sub sampling:* In this method of DWT sub sampling, all the HH coefficients are discarded.
3) *Half sampled DWT sampling:* Similarly, by the half sampled DWT sub sampling, means taking odd and even coefficients from either HL, or HL set and discarding the HH coefficients.

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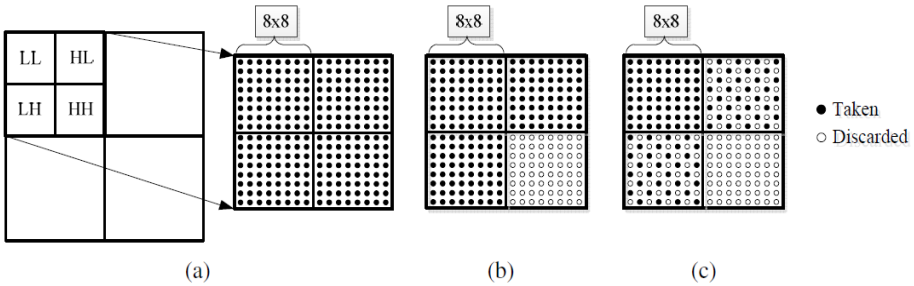

Fig.3 Sub-sampling of the DWT coefficients: (a) fully sampled; (b) quarterly sampled; (c) half sampled

After the DWT sub sampling, the 8-point DCT is applied to these DWT coefficients. To achieve further compression, a JPEG-like quantization is performed. In this stage, most of the higher frequency components are rounded to zero. The quantized coefficients are encoded using Huffman algorithm. The entire hybrid DWT-DCT compression process with Huffman encoding is illustrated in Fig.4.

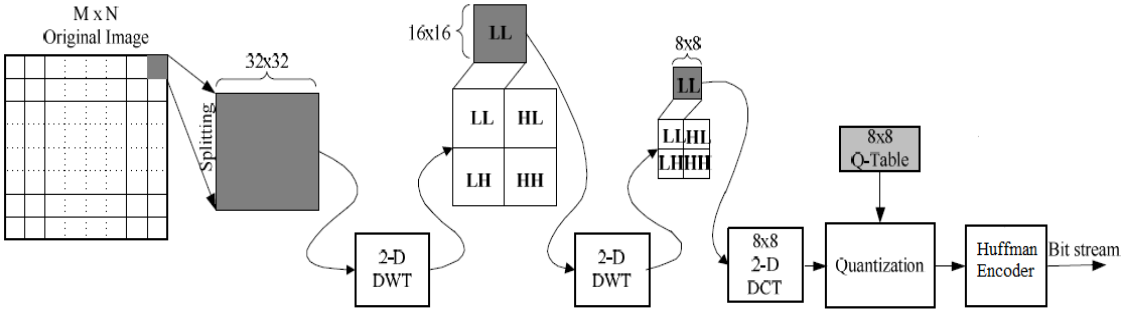

Fig.4 Block diagram of the proposed hybrid DWT-DCT, Huffman algorithm: Compression

B. The process of data reconstruction

The bit stream after the Huffman coding is the compressed data of interest is decoded by Huffman decoding algorithm. Furthermore, the output rescaled data are dequantized by using the same JPEG quantisation table used for the compression procedure. The dequantized data are passed through 2-D inverse DCT. The data obtained after inverse 2-D DCT is then passed through the 2-D inverse DWT at first level. During the 2-D inverse DWT, zero values are padded in place of the detail coefficients. Finally, the output from first level 2-D DWT passed through the 2-D inverse DWT in second level and hence the final image is reconstructed. The entire reconstruction procedure is illustrated in Fig.5.

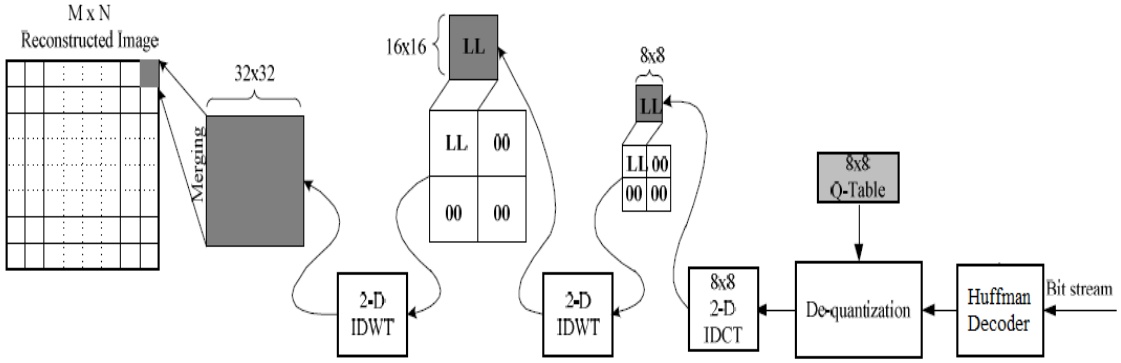

Fig.5 Block diagram of the proposed hybrid DWT-DCT, Huffman algorithm: Reconstruction

IV. PERFORMANCE EVALUATION PARAMETERS

Image compression technique introduces some amount of distortion in the reconstructed image. Therefore, evaluation of the image quality is an important issue. The quality of reconstructed images can be evaluated in terms of following parameters.

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A. *Peak Signal to Noise Ratio (PSNR)*

Peak Signal to Noise Ratio (*PSNR*) has been the most popular tool for the objective quality measurement of the compressed image and video.

B. *Compression Ratio (CR)*

In the process of image compression, it is important to know how much detail (important) coefficient one can discard from the input data in order to preserve critical information of the original data. Compression ratio (*CR*) is a measure of the reduction of the detail coefficient of the data.

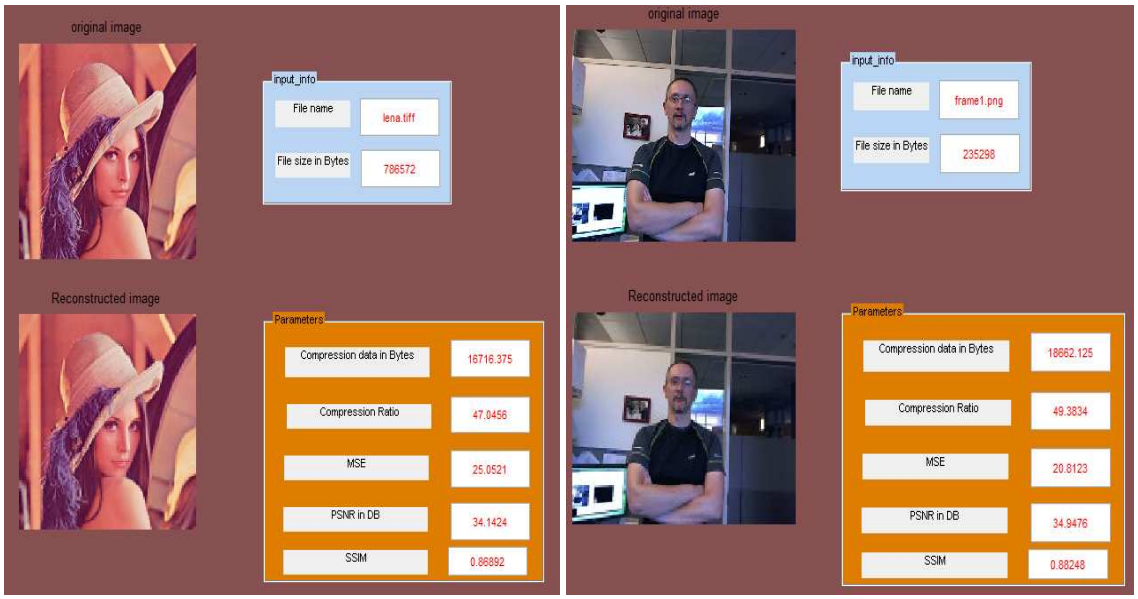
C. *Variance*

Variance is another tool to calculate the performance of image compression algorithm. Variance describes how far certain value deviates from the mean. It's the measure of variability from an average. The lower the variance, higher will be the energy compaction property. The energy compaction property defines that most of the information signal tends to concentrate in the low frequency component. Higher the energy compaction property, the better is the compression algorithm.

D. *Structural Similarity (SSIM) Index*

The main paradigm of *SSIM* is based on the assumption that the image signals are highly structured, i.e. the neighbouring pixels of the image signals are highly correlated. This correlation carries important information about the structure of the image in the visual perception. Therefore, *SSIM* provides a good approximation to the perceived image quality. During the data compression, the structures of the reconstructed data are distorted. This distortion can be analysed using *SSIM* index.

V. RESULTS



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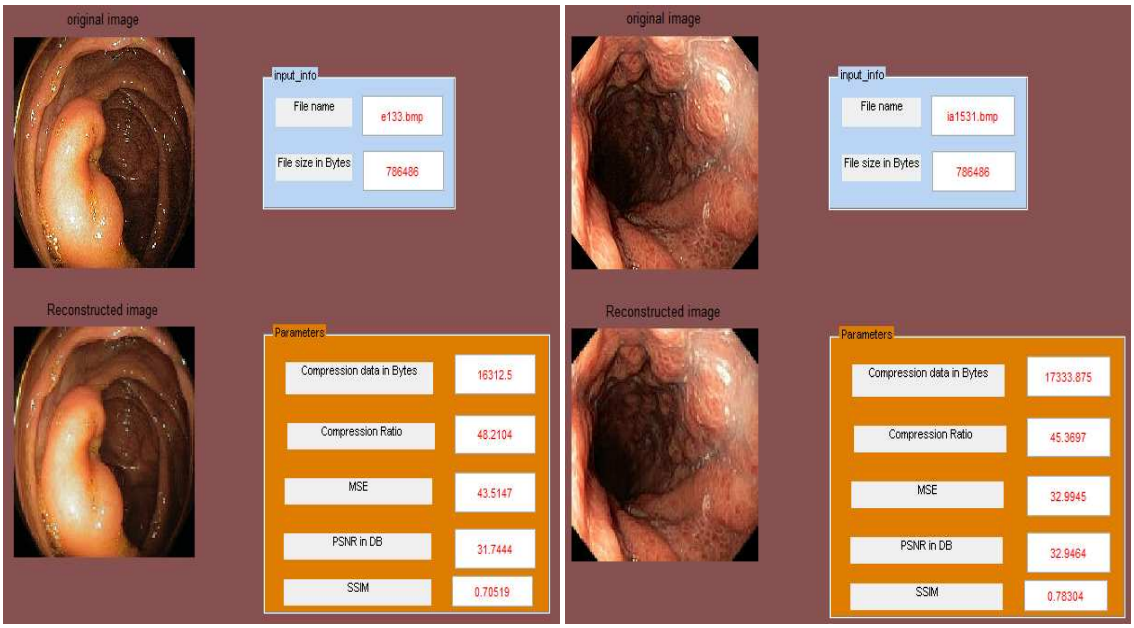

Fig. 6 Original & Compressed images with their parameters.

VI. CONCLUSIONS

The approach of combining multiple transformations i.e. DWT-DCT, and Huffman coding has been successfully presented in this research work. The hybrid algorithm compensated the demerits of standalone DCT and DWT. The proposed algorithm reduced the blocking artifacts that appeared in case of DCT. In standalone DCT, the entire image/frame is divided into 8 x 8 block in order to apply 8 point DCT. Whereas, in case of hybrid algorithm, image/frame is first divided into 32 x 32 blocks and two level of DWT is performed for these 32 x 32 block image. The output after the two level of DWT becomes 8 x 8 and hence the 8 point DCT is applied for that 8 x 8 output. Then this will be encoded by Huffman encoding technique. The difference in block size causes the blocking artifacts in case of standalone DCT. Similarly, the contouring effect of DCT has also been reduced by using proposed hybrid DWT-DCT, Huffman algorithm.

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