Efficient Hybrid Transform Scheme for Medical Image Compression

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ABSTRACT
In recent times, developing hybrid schemes for effective image compression has gained enormous popularity among researchers. This research paper presents a proposed scheme for medical image compression based on hybrid compression technique (DWT and DCT). The goal is to achieve higher compression rates by applying different compression thresholds for the wavelet coefficients of each DWT band (LL and HH) while DCT transform is applied on (HL and LH) bands with preserving the quality of reconstructed medical image. The retained coefficients are quantized by using adaptive quantization according to the type of transformation. Finally the entropy coding (variable shift coding) is used to encode the quantization indices. Experimental results show that the coding performance can be significantly improved by the hybrid DWT-DCT algorithm.

Keywords
image compression; quasi lossless compression; adaptive quantization; hybrid scheme; DWT; DCT ;medical image.

1. INTRODUCTION
Wavelet transform provides numerous desirable properties, such as efficient multi-resolution representation, scalability, and embedded coding with progressive transmission, which are beneficial to the image compression applications [1]. Wavelet based multi-resolution representation matches the Human Visual System, specifically the higher detail information of an image is represented by the shorter basis function with higher spatial resolution and the lower detail information is represented by the larger basis function with higher spectral resolution [2]. The recently standardized image compression scheme known as JPEG 2000 uses discrete wavelet transform as the underlying transform algorithm [3]. Recently some hybrid coding techniques are developed. H. Hsin et al proposed a hybrid algorithm using SPIHT and EBC (embedded block coding) to code low frequency and high frequency wavelet coefficients, respectively; the intermediate coding results of low frequency coefficients are used to facilitate the coding operation of high frequency coefficients [4]. Another hybrid scheme is proposed by combining Kohonen's Self Organizing Feature Map (SOFM) based Vector Quantization (VQ) coding and Set Partitioning in Hierarchical Trees (SPIHT) coding for effective compression of images [5].

In [6] a strategy to increase the compression ratio with simple computational burden and excellent decoded quality is presented. In [7] DCT and modified SPIHT algorithm are adopted to encode DCT coefficients. The proposed algorithm also provides the deblocking function in low bit rate in order to improve the perceptual quality. A lifting scheme wavelet-based transform with a modified entropy coding algorithm is proposed in [8-10]. It showed how block subband coding leads to increase the compression factor with preserve the quality.

In this paper, a novel algorithm for medical image compression is developed using 9/7 Tap wavelet filter, DCT transform and optimized entropy-based coding technique. The diagram of proposed work is shown in the Figure 1.

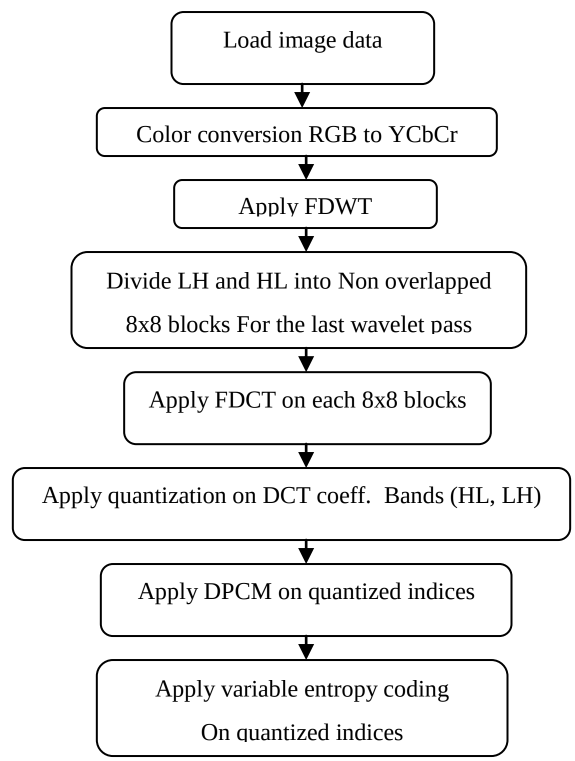

Fig 1: Proposed method diagram

In Sec-2, the proposed algorithm and its implementation are presented. In Sec-3, the conducted test which is evaluating the proposed scheme is detailed. Finally the main conclusions are summarized in Sec-4.

2. PROPOSED CODING ALGORITHMS STEPS

In this section detail steps of the proposed medical image compression are proposed as follows:

2.1 Color Space Conversion (RGB to YCbCr))

YCbCr refers to the color resolution of digital component video signals, which is based on sampling rates. In order to compress bandwidth, Cb and Cr are sampled at a lower rate than Y, which is technically known as "chroma subsampling." This means that some color information in the image is being discarded, but not brightness (luma) information.

Y = 0.2989 * R + 0.5866 * G + 0.1145 * B

Cb = -0.1687 * R - 0.3312 * G + 0.5 * B

Cr = 0.5 * R - 0.4183 * G - 0.0816 * B

2.2 Forward Discrete Wavelet Transform (FDWT)

Discrete Wavelet transform (DWT) represents an image as a sum of wavelet functions (wavelets) with different locations and scales. Any decomposition of an image into wavelets involves a pair of waveforms: one to represent the high frequencies corresponding to the detailed parts of an image (wavelet function) and one for the low frequencies or smooth parts of an image (scaling function).

The filter which is used for this transformation is a non reversible filter (real to real transform 9/7Tap) and can only be used for lossy coding. In figure 2 the wavelet of 2 levels of decomposition is shown:

Fig 2: Wavelet decomposition (no. of pass = 2)

After applying FDWT on the medical image's data, one can obtain different level of bands. LL and HH band's coefficients are directly sent to the adaptive quantizer according to the nature of bands. The remaning bands (HL and LH) coefficients are subjected to DCT transformation.

2.3 Forward Discrete Consine Transform (FDCT)

Each of HL and LH bands are divided into 8X8 blocks and converted to frequency domain using 2D FDCT equation:

$$D(u,v) = \frac{1}{\sqrt{2N}} C(u)C(v) \sum_{x=0}^{N-1}\sum_{y=0}^{N-1} P(x,y)\cos\left[\frac{(2x+1)u\pi}{2N}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right]$$

where

$$C(i) = \begin{cases} 1/\sqrt{2} & \text{if} \quad i=0 \\ 1 & \text{if} \quad i>0 \end{cases}$$

2.4 DCT Quantization

DCT block's coefficients of Y component must be quantized using the following luminance quantization matrix:

The quantization is done by simply dividing each DCT's coefficient by its corresponding value in the quantization matrix and then rounding to the nearest integer.

$$\begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 60 & 59 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

The Cb and Cr components are quantized using chrominance quantization matrix:

$$\begin{bmatrix} 17 & 18 & 24 & 47 & 99 & 99 & 99 & 99 \\ 18 & 21 & 26 & 66 & 99 & 99 & 99 & 99 \\ 24 & 26 & 55 & 99 & 99 & 99 & 99 & 99 \\ 47 & 66 & 99 & 99 & 99 & 99 & 99 & 99 \\ 99 & 99 & 99 & 99 & 99 & 99 & 99 & 99 \\ 99 & 99 & 99 & 99 & 99 & 99 & 99 & 99 \\ 99 & 99 & 99 & 99 & 99 & 99 & 99 & 99 \\ 99 & 99 & 99 & 99 & 99 & 99 & 99 & 99 \end{bmatrix}$$

In the resulting matrix many of the higher frequency components are rounded to zero, and many of the rest become small positive or negative numbers.

2.5 DWT Quantization

The LL, HH coefficients must be quantized using adaptive quantization. The luminance component Y requires the small step of quantization while Cb and Cr need a large step. After this step, a large sequence of zeros is obtained especially in HH part of the image.

2.6 DPCM and Mapping to Positive

Basic concept of DPCM - coding a difference, is based on the fact that most source signals show significant correlation between successive samples so encoding uses redundancy in sample values which implies lower bit rate.

The forward differential pulse code modulation is applied on the quantized (LL band) wavelet coefficients and quantized DC coefficients of DCT transform. And then all the coefficients must be converted into positive values by mapping to positive technique. The block diagram of these steps is shown as in figure 3.

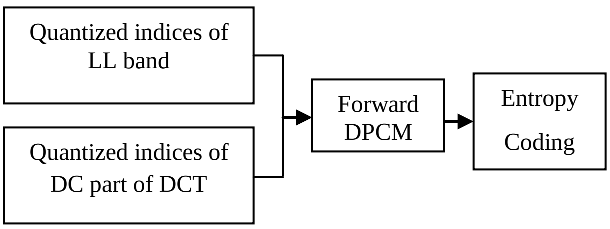

Fig 3: Block diagram of DPCM and Mapping

2.7 Variable Entropy Coding

The proposed coding scheme is a variable shift coding technique which gives a few bits to the short codeword and many bits to the long codeword. The main idea behind the shift coding algorithm is to find the maximum hybrid transform coefficients in the data set and optimized these coefficients to take a small numbers of bits. The other coefficients within the set are coded with the same number of bits [8].

3. DECODING ALGORITHM

The reconstructed image is obtained by applying the inverse steps of coding process. Figure 4 and 5 show the coding and decoding processes' steps.

4. TEST RESULTS

The tests are performed on medical images taking by MRI with two different sizes, brain (256X256) and pulmonary (512x512) see figure 6. To show the effect of involved parameters on the compression ratio, different values of scaling factor (α) are used. α affects the quantization steps (QY and QCb, QCr) for both DWT and DCT coefficients, see figure 7. Table 1 and 2 present the test results for the number of pass 2 and 3 respectively. The quatization parameters are fixed as QY = 35, QCb = 40, QCr = 40.

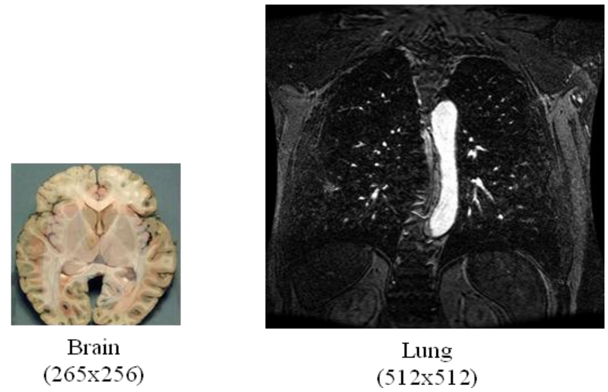

Fig 6: Image used in tests

Table 1. Resulting parameters where no. of pass = 2

Image	DWT Quantization factor	DCT Quantization factor	Compression ratio	PSNR
brain	0.2	0.2	28.88	35.96
	0.5	0.5	42.78	34.24
	1.0	1.0	58.15	32.41
lung	0.2	0.2	28.10	35.79
	0.5	0.5	42.59	33.73
	1.0	1.0	59.66	31.25

Table 2. Resulting parameters where no. of pass = 3

Image	DWT Quantization factor	DCT Quantization factor	Compression ratio	PSNR
brain	0.2	0.2	17.7	35.8
	0.5	0.5	32.9	33.2
	1.0	1.0	51.9	29.2
lung	0.2	0.2	21.89	35.7
	0.5	0.5	34.89	33.1
	1.0	1.0	54.50	28.8

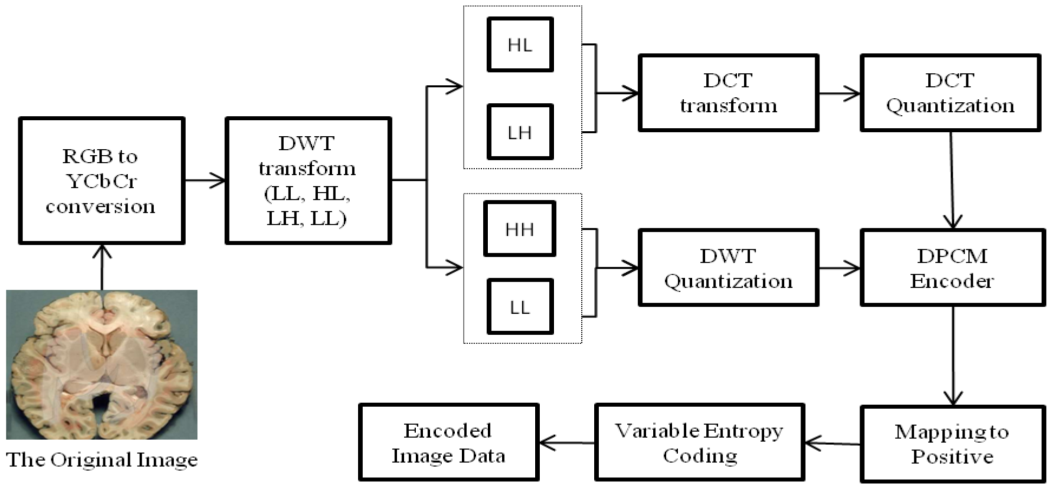

Fig 4: Coding Process

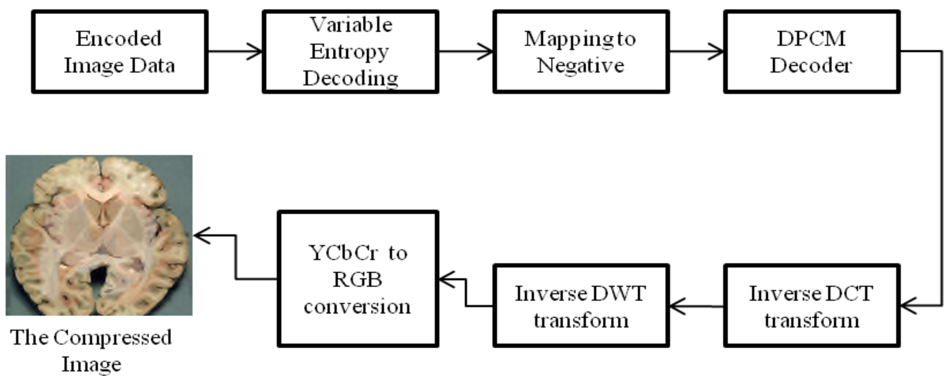

Fig 5: Decoding Process

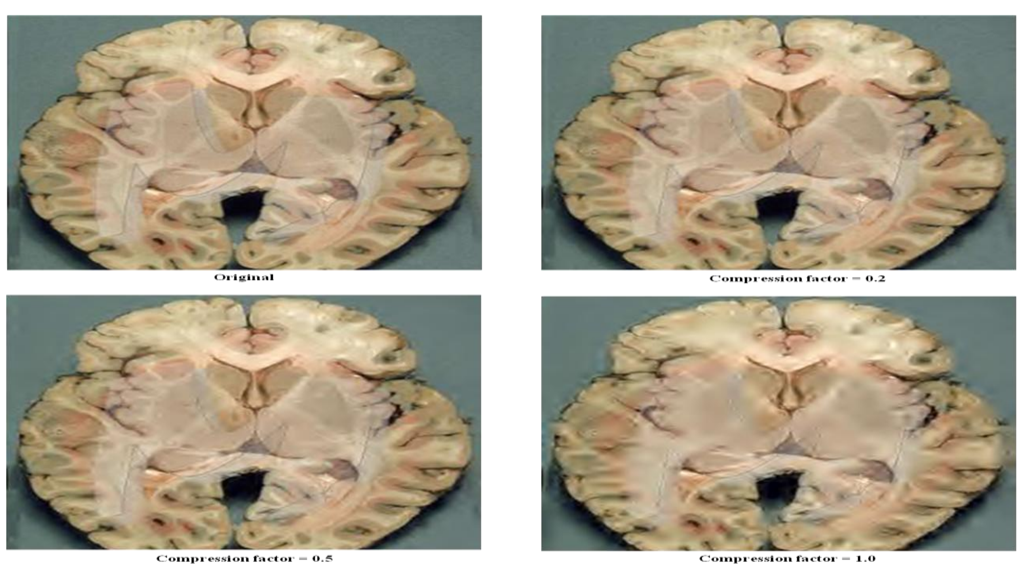

Fig 7: Compressed images with different compression factors and number of DWT passes = 2

5. CONCLUSIONS

In this paper a new hybrid scheme for medical image compression is proposed. This method is based on both DWT and DCT compression techniques. This hybrid compression technique is tested against different medical images using different values of compression factors (i.e. DWT and DCT quantization factors). As the quantization factors increase the Compression ratio increase and the quality measurement (PSNR) decrease.

Experimental results show that these compressed medical images preserve its quality where quantization factor is less than 0.5. Where quantization factor is larger than 0.5, the constructed image after compression will begun slowly losing its quality.

6. REFERENCES

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