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Patient Monitoring System through Mobile Devices

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ABSTRACT: Medical personnel, nowadays, use mobile devices to access patient's information ubiquitously. Security, authentication and privacy on mobile devices must be met in order for the complete adoption of mobile devices in medical field. Also, the bio medical image compression involved should provide a good compromise between the quality of the reconstructed image and the compression ratio involved. The use of hybrid algorithms, seem to meet both the demands. This paper presents one such hybrid algorithm in which Discrete Cosine Transform (DCT) is performed on the approximation coefficients of Discrete Wavelet Transform (DWT). The security aspect is met by performing LSB level substitution in one of the detail sub bands. Results have shown the hybrid algorithm to yield better compression ratio and quality when compared to the two level decomposition performed by DWT.

I. INTRODUCTION

Medical facilities are adapting technology to allow mobile data retrieval. Mobile devices aid medical personnel by allowing them to access information ubiquitously. Security, authentication and privacy on mobile devices must be met in order for their complete adoption in medical field. This can be achieved by digital watermarking of medical images to authenticate patient information on mobile devices. Also, it is necessary that the digital watermark that is so used is imperceptible to the viewer and can withstand different compression rates and algorithms in order for the information embedded in the image to survive. Although, there are several watermarking techniques available, not all of them take into consideration, the low memory and the low computational capacity of mobile devices into account.

Also, medical images tend to be of large size. This large file size makes compression a necessity for a mobile unit to handle it. The choice on compression technique has to be made carefully, as fidelity of the image is lost on performing a lossy compression. This is an essential criterion for diagnostic purposes. It would be more appropriate to convert the medical images which are mostly in DICOM format to standard JPEG and then use a JPEG compression due to the importance of embedded information.

The Joint Photographic Expert Group (JPEG) was developed in 1992, based on DCT. It has been one of the most widely used compression methods [1][2]. Although hardware implementation for the JPEG using the DCT is simple, the noticeable "blocking artifacts" across the block boundaries cannot be neglected at higher compression ratio. In addition, the quality of the reconstructed images is degraded by the "false contouring" effect for specific images having gradually shaded areas [3]. The main cause of false contouring effect is heavy quantization of the transform coefficients and looks like a contour map. The Discrete Wavelet Transform (DWT) based coding, on the other hand, has been emerged as another efficient tool for image compression [4-6] mainly due to its ability to display image at different resolutions and achieve higher compression ratio.

In order to benefit from the respective strengths of individual popular coding schemes, a new scheme, known as hybrid-algorithm, has been developed where two transform techniques are implemented together. There have been few efforts devoted to such hybrid implementation. In [8] the authors have presented a transformation scheme involving the application of DCT on DWT coefficients with a restricted block size of 32.

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In [7] the authors have applied various compression thresholds for the wavelet coefficients of each DWT band (LL and HH) and applied DCT transform on (HL and LH) bands to achieve high compression rates. In [9], the author has performed watermarking in the transform domain. Watermarking has been performed after the implementation of DWT-DCT i.e. onto the transformed coefficients but it doesn't deal with the compression aspect therefore it keeps all the sub bands to reconstruct the image. In [10], Singh et al. have applied similar hybrid algorithm to medical images that uses 5-level DWT decomposition. Because of the 5 levels of DWT involved, the scheme requires large computational resources and is not suitable for use in mobile devices.

In [7],[8] and [19] the hybrid algorithms explained do not take into consideration the security aspect but only compression aspect. In [9] the hybrid algorithm involved takes into consideration the security aspect only. This paper deals with both security aspect and compression aspect by the implementation of Least Significant Bit (LSB) substitution onto one of the detail sub bands obtained after performing hybrid DWT-DCT.

A) DISCRETE COSINE TRANSFORM

The discrete cosine transforms is a technique for converting a signal into elementary frequency components [11]. It represents an image as a sum of sinusoids of varying magnitudes and frequencies.

The DCT for an N×N input sequence can be defined as follows [1]:

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

where,

$B(u) = \begin{cases} \frac{1}{\sqrt{2}} & if \quad u=0 \\ 1 & if \quad u>0 \end{cases}$, $M(x,y)$ is the original data of size $x \times y$.

The input image is first divided into 8×8 blocks; then the 8-point 2-D DCT is performed. The DCT coefficients are then quantized using an 8×8 quantization table, as described in the JPEG standard. The quantization is achieved by dividing each elements of the transformed original data matrix by corresponding element in the quantization matrix Q and rounding to the nearest integer value as shown in Eq. (2):

$$D_{quant}(i,j) = round\left(\frac{D_{DCT}(i,j)}{Q(i,j)}\right) \quad (2)$$

Further compression is achieved by applying appropriate scaling factor. In order to reconstruct the data, the rescaling and the de-quantization processes are performed. The de-quantized matrix is then transformed back using the inverse-DCT. The entire procedure is shown in the following figure.

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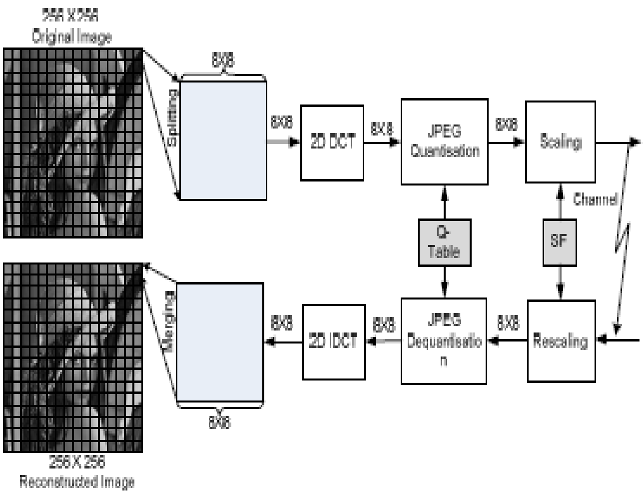

Fig 1

B) DISCRETE WAVELET TRANSFORM

Wavelets are special functions which, in a form analogous to sines and cosines in Fourier analysis, are used as basal functions for representing signals [12]. For 2-D images, applying DWT corresponds to processing the image by 2-D filters in each dimension. The filters divide the input image into four non-overlapping multi-resolution sub-bands LL1, LH1, HL1 and HH1. The sub-band LL1 represents the coarse-scale DWT coefficients while the sub-bands LH1, HL1 and HH1 represent the fine-scale of DWT coefficients [13-14]. To obtain the next coarser scale of wavelet coefficients, the sub-band LL1 is further processed until some final scale N is reached. When N is reached we will have 3N+1 sub-bands consisting of the multi-resolution sub-bands LLN and LHx, HLx and HHx where x ranges from 1 until N.

Due to its excellent spatio-frequency localization properties, the DWT is very suitable to identify the areas in the host image where a watermark can be embedded effectively. In particular, this property allows the exploitation of the masking effect of the human visual system such that if a DWT coefficient is modified, only the region corresponding to that coefficient will be modified. In general most of the image energy is concentrated at the lower frequency sub-bands LLx and therefore embedding watermarks in these sub-bands may degrade the image significantly. Embedding in the low frequency sub-bands, however, could increase robustness significantly [15]. On the other hand, the high frequency sub-bands HHx include the edges and textures of the image and the human eye is not generally sensitive to changes in such sub-bands. This allows the watermark to be embedded without being perceived by the human eye. The procedure involved in 2D forward DWT is illustrated by the following figure:

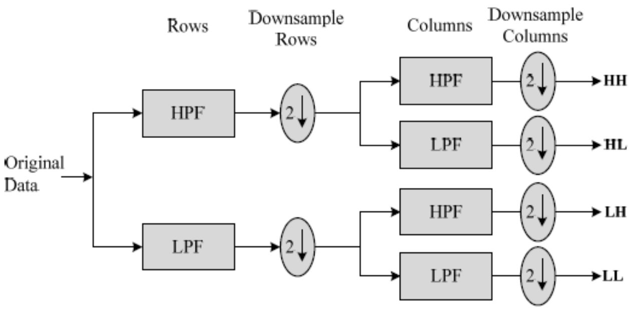

Fig 2

The process of multilevel decomposition in DWT is explained clearly by the following figure:

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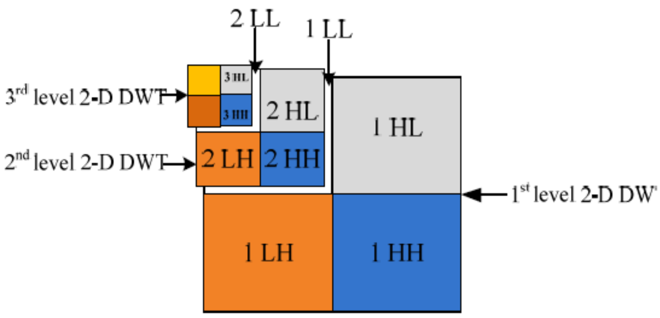

Fig 3

C) LSB LEVEL SUBSTITUTION

In this method of watermarking, the message is embedded into least significant bits of each pixel in an image. Therefore it doesn't withstand the compression when performed in the spatial domain. Hence, LSB level substitution is performed in the transform domain, after the compression part gets over. If the message is in the form of an image the reconstructed watermark will be a binary image.

II. PROPOSED METHOD

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 is first divided into blocks of N×N where N can be either 64 or 128. Each block is then decomposed using the 2-D DWT. Low-frequency coefficients (LL) are passed to the next stage where the high frequency coefficients (HL, LH, and HH) are discarded [17].

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). The watermark is applied to one of the detail sub bands through LSB substitution. Finally, the image and the watermark is reconstructed following the inverse procedure [16]. During the inverse DWT, zero values are padded in place of the detail coefficients. The figure below explains the compression aspect alone.

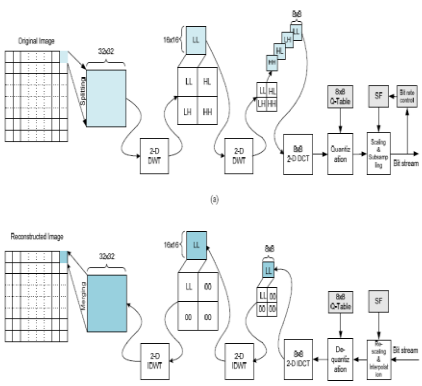

Fig 4

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The algorithm involved is given in a step by step manner as follows:

Step 1: Divide the image into various blocks of size 64 or 128

Step 2: Apply DWT to decompose the cover host image into four non-overlapping multi-resolution sub-bands: LL1, HL1, LH1, and HH1.

Step 3: Apply DWT again to sub-band LL1 to get four smaller sub-bands and choose the HL2 or HH2 or LH2 sub-band and perform LSB level substitution.

Step 4: Divide the sub-band LL2 into 8x 8 sub blocks and apply DCT on to them

Step 5: In order to improve the compression ratio perform quantisation on the transformed coefficients.

Step 6: To further improve the compression ratio divide the quantised coefficients by scaling factor.

Step 7: The quantised coefficients are then zigzag scanned and then suitably encoded.

Step 8: In order to recover the watermark and also to reconstruct the image the reverse process is followed.

III. EVALUATION CRITERION

In this section, the performance of the algorithms using two popular measures: compression ratio (CR) and peak signal to noise ratio (PSNR) has been analysed.

A.) PSNR:

The PSNR in decibel is evaluated as follows:

$$PSNR = 10\log_{10}\frac{I^2}{MSE}$$

where, I is the maximum intensity level (= 255).

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(A_{i,j} - B_{i,j}\right)^2$$

where, A is the original image and B is the reconstructed image of size M × N.

B.) Compression ratio (CR):

The compression ratio is defined as follows:

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

The resulting CR can be varied based on the desired image quality and the level of compression depends on the QT and the SF.

IV. RESULTS OF HYBRID DWT-DCT

The reconstructed images from hybrid DWT-DCT algorithm and the 2 level decomposition of DWT are as follows:

Fig 5

Hybrid(BS=128,PSNR=34 DWT-DWT(BS=128,PSNR=34, CR=33.33% CR=31%)

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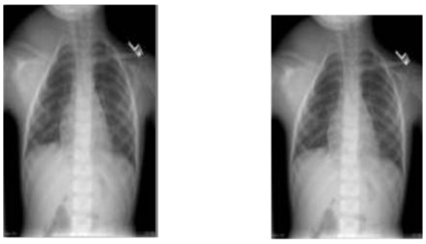

Fig 6

Hybrid(BS=64,PSNR=34 DWT-DWT(BS=64,PSNR=34, CR=40% CR=36%)

The above comparison shows that for a given PSNR of 34, CR of the proposed method is better than 2 level decomposition of DWT, for block sizes of both 64 and 128.

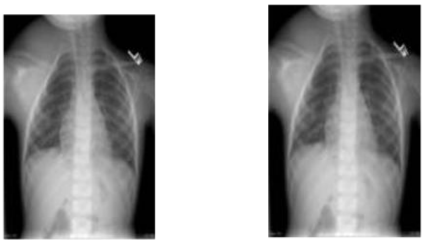

Fig 7

Hybrid(BS=64,CR=40% DWT-DWT (BS=64, CR=40% PSNR=33.48)PSNR=34.4)

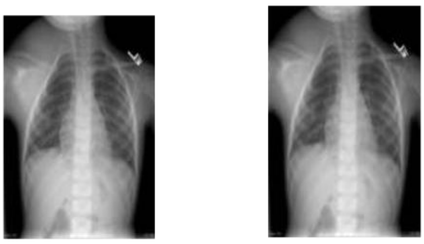

Fig 8

Hybrid(BS=128,CR=40% DWT-DWT (BS=128, CR=40% PSNR=32.76) PSNR=31.82)

The above comparison shows that for a given CR of 40%, PSNR of the proposed method is better than 2 level decomposition of DWT, for block sizes of both 64 and 128.

V. MOBILE CONSTRAINTS

The mobile devices impose a lot of constraints on the image compression and the secure contact that needs to be established between the doctor and the patient or the hospital. Some of the constraints are listed as follows:

a) Display Size:

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It is a well known fact that, the display size of mobile device is very small when compared to that of a computer. This should not in anyway, hinder the diagnosis of the disease by the doctor.

b) Computational Complexity:

It should be kept in mind that, the resources available for computational purposes in a mobile device is limited [18]. Therefore the algorithm which is used should not be too complex.

c) Computational time:

The communication between the doctor and the patient or the hospital should be of real time. Therefore the computational time should be as less as possible.

d) Energy Consumed:

The entire process involving the decompression and watermark recovery at the mobile device should be such that it doesn't drain the mobile device's charge. Therefore, the power consumed should be, as minimum as possible.

VI. CONCLUSION

In this paper, we present a new hybrid scheme combining the DWT and the DCT algorithms under high compression ratio constraint. The algorithm performs the DCT on the lowest level DWT coefficient. It is tested on several types of images, of which chest X-ray images have been shown here and the results of this exhaustive simulation show an improved performance, over 2 level decomposition DWT and other hybrid schemes. Also, the security aspect has been taken care by the use of LSB level substitution. The new scheme reduces the false contouring effect 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. The proposed scheme has medium computational complexity and is intended to be used for mobile devices, facilitating the doctor to diagnose the patient's disease from anywhere.

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