Lossless Compression of Color Image by Implementing Hybrid Transformation of DWT, DKT and DCT

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Abstract— Image compression is the method to decrease insignificance and redundancy of image data in order to store or transmit image in a competent form. The essential information is extracted by using different transform techniques such that it can be reconstructed without ruining quality and information of the image. The paper presents a peculiar Hybrid Wavelet Transform genesis technique for Image compression using two orthogonal transforms. The concept of hybrid wavelet transform is to combine the attributes of two or more different orthogonal transform wavelet to attain the vitality of multiple transform wavelet. Here approach is to generate hybrid wavelet transform using three orthogonal transform using together Discrete Cosine transform, Discrete Wavelet transform and Discrete Kekre Transform which all are lossy compression techniques. On several image simulation has been carried out. The result has shown that hybrid transform wavelet performance is best as compared to transform wavelets. Here the hybrid of DWT, DCT and DKT provides the best result amongst the individual mentioned transforms.

Keywords: Image compression, Hybrid Wavelet Transform, Discrete Wavelet Transform, DWT, Discrete Cosine Transform, DCT, Discrete Kekre Transform, DKT

I. INTRODUCTION

The advent of high speed computing devices and rapid development in the field of communication has created a tremendous opportunity for various computer based image applications. The amount of data required to store a digital image is continually increasing and overwhelming the storage devices. Therefore it is required to store images using lesser number of bits than its original size. Image compression deal with this problem. It reduces the number of bits required to represent the image. Hence, reduction in file size allows more image to be stored in a given amount of memory space. It also reduces the time required for the image to be sent over the internet or downloaded from web pages. There are two types of compression methods: lossless compression and lossy compression. The lossless image compression preserves exact data of the original image.

The lossy compression will not preserve the absolute data content of the original image but preserves some specified level of image quality. It rely on the conception of compromising the accuracy of reconstructed image in order to reinforce the compression ratio. If the resulting distortion is endurable the increase in compression can be significant. Therefore lossy compression is frequently used as compared to lossless compression. The measure of image compression achieved is defined as compression ratio. Generally used lossy compression technique is Transform Coding such as Discrete Cosine Transform (DCT) used in JPEG and Wavelet Transform used in JPEG2000 [1].

Transform coding technique is based on modifying the transform of an image. Here, reversible linear transform is used to map image into a set of transform coefficients and then these coefficients are quantized and coded. In transform coding initially DCT was popular. It separates an image into different frequency component. Low frequency component provides high energy compaction as compared to high frequency component. Therefore they are discarded. Elimination of this high frequency component provides the transformed image with sparse low frequency component. Image reconstructed from these sparse low frequency elements is compressed image without ruining much data content in original image [2]-[4].

Since last two to three decades wavelet transform is adopted for enormous applications, often replacing widely used Fourier Transform. Traditional signal processing technique such as Fourier Transform are poorly suited for analyzing signals which have sharp abrupt transitions superimposed on lower frequencies. Wavelet Transform provides an approach to analyze such data. An important property of wavelet is its Multiresolution capability which helps to view the image at different scales. Recently Hybrid Technique is in progression, in which one transform is combined with another transform to amalgamate the advantages of both transforms [5]-[7].

Initially Haar Wavelet were focused and widely used for compression [4]-[8]. In recent literature wavelets of other orthogonal transforms have been introduced. These transforms include Walsh [6]-[10], DCT [11]-[12], Kekre [13]-[14], and Hartley Transform [15]-[17] are proposed. The wavelet transform in various applications have performed better than their respective orthogonal transform [8], [18] and [19].

The paper presents the inventive Hybrid Wavelet Transform genesis methodology, which generates Hybrid wavelet transform of any three orthogonal transform. So the concept behind using hybrid wavelet transform is to exploit the strength of both the transform wavelets. Here hybrid wavelet transform is generated using Discrete Walsh Transform (DWT), Discrete Cosine Transform (DCT), and Discrete Kekre Transform (DKT). Another objective of this paper is to enhance compression ratio so as to reduce the storage size of an image. For this a combination of three lossy compression method such as Huffman coding and run length encoding is used. Here Huffman coding is applied on symbols or runs rather than single symbol. This is referred here as Extended Huffman Compression [20] and [21]. The experimental result convinces that the hybrid wavelet transforms are better than their wavelet transforms and due to encoding a higher compression ratio is achieved.

II. PROPOSED ALGORITHM

Proposed new algorithm for color image compression and decompression uses the concept of generating hybrid
wavelet transform from three orthogonal transforms Discrete Wavelet Transform, Discrete Kekre Transform and Discrete Cosine Transform. Schematic diagram of process followed is shown in fig. 1 and 2.

A. Color Image Compression:

Fig. 1 shows the proposed algorithm for color image compression and fig. 2 shows its decomposition method to recover the original image. To compress 256x256 color image first RGB color image is factorized into its Luma component (Y), Blue deference (Cb) and Red deference (Cr) of croma components. The conversion of RGB color image into YCbCr is performed by using following equations.

\[
Y = 16 + 65.481 \cdot R + 128.553 \cdot G + 24.966 \cdot B \\
C_b = 128 - 37.797 \cdot R - 74.203 \cdot G + 112.0 \cdot B \\
C_r = 128 + 112.0 \cdot R - 93.786 \cdot G - 18.214 \cdot B
\]  

Each extracted component is first blocking in to 32x32 pick cells. Each 32x32 pick cell block is then transformed through 2d DWT and converted into LL, LH, HL and HH components of size 16x16 pick cells. Here LL represents the approximation image, LH represents horizontal details, HL represents vertical details and HH represents diagonal details of each 32x32 block of image. Here LH, HL and HH details are replaced by zero and LL details are used for further process.

![Fig. 1: Proposed Hybrid Wavelet Transform based Image Compression Algorithm](image)

Each LL details of the 16x16 pick cell size are now passed through 8x8 DKT. The advantage of the Kekre’s transform matrix is that do not need of size having integer power of 2. It should be of any size NxN. In DKT matrix all diagonal and upper diagonal elements are 1 whereas; all lower diagonal elements except the elements just below the diagonal are zero. Kekre transform matrix of size 6x6 is shown below for example.

\[
\text{DKT Matrix (16x16)} = \begin{bmatrix}
1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
-1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\
0 & -1 & 1 & 1 & 1 & 1 & 1 & 1 \\
0 & 0 & -1 & 1 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & -1 & 1 & 1 & 1 & 1 \\
0 & 0 & 0 & 0 & -1 & 1 & 1 & 1 \\
0 & 0 & 0 & 0 & 0 & -1 & 1 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 \\
\end{bmatrix}
\]  

The DKT transformed LL details of size 16x16 are now re-blocked in to 8x8 size of pick cells. 2d DCT of size 8x8 is now implemented in to each 8x8 DKT transformed LL details. The DCT transform equation can be expressed as:

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

Each 8x8 DCT elements are compressed through Quantization means dividing by some specific 8x8 matrix which is called \(Q_{\text{matrix}}\) and rounding to the nearest integer value as shown in equation (6).

\[
D_{\text{quant}}(i,j) = \text{round} \left( \frac{D_{\text{DCT}}(i,j)}{Q_{\text{matrix}}(i,j)} \right)
\]  

Here \(Q_{\text{matrix}}\) is decided by the user to keep in mind that it gives Quality levels ranging from 1 to 100, where 1 gives the poor image Quality and highest compression ratio while 100 gives best Quality of decompressed image and lowest compression ratio. The standard \(Q_{\text{matrix}}\) can be shown as equation (7).

\[
Q_{\text{matrix}} = \begin{bmatrix}
16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\
12 & 14 & 19 & 26 & 58 & 60 & 55 & 69 \\
14 & 13 & 16 & 24 & 40 & 57 & 79 & 56 \\
14 & 17 & 22 & 29 & 51 & 97 & 90 & 62 \\
18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\
24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\
49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\
72 & 92 & 95 & 98 & 112 & 100 & 103 & 91 \\
\end{bmatrix}
\]  

The quantized data is encoded by arithmetic encoding technique. All encoded sequences are now save in an text format, which shows less required disk space to be store then original image. This encoded text file may also transmit, which will require less channel space and will be decompressed on the receiving side.

B. Color Image Decompression:

Decompression of the compressed color image is exact reverse process as shown in fig. 2. Encoded compressed text file is first decoded by inverse implementation of arithmetic encoding, which is arithmetic decoding. This decoded data is inversely quantized by using similar Qmatrix as used in compression process. Inverse quantization is performed as shown in equation (8).

\[
D_{\text{dequant}}(i,j) = Q(i,j) \cdot D_{\text{quant}}(i,j)
\]  

The de-quantized matrix is inversely transformed by using 8x8 2d-inverse DCT. The 2d-IDCT can be expressed as in equation (9).

\[
P(x,y) = \frac{1}{2N} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} C(i) C(j) D(i,j) \cdot \cos \left( \frac{(2x+1)i\pi}{2N} \right) \cos \left( \frac{(2y+1)j\pi}{2N} \right)
\]

IDCT transformed 8x8 details is now rearranged in to 16x16 matrices and transformed through IDKT by using Kekre’s transform matrix of size 16x16. Now 16x16 inverse DWT transform is performed. Its output is in 32x32 pick cells size. This data is now regrouped in to single matrix by 32x32 inverse blocking.
Here we get back the color image components in the form if Y, Cb and Cr. Now these color components are reconverted in RGB color format to reconstruct the original color image, which is our decompressed color image.

### III. MATLAB SIMULATION

This section shows the MATLAB simulation results of proposed method. This paper shows image compression and decompression results of eight well-known color images of size 256x256. All color images are first compressed through proposed Hybrid Wavelet Transform using DWT, DKT and DCT together. Compressed file is again decompressed and recovered lossless color image.

Here fig. 3 shows the original RGB color image of a girl 1. Its Luma component (Y), Blue deference (Cb) and Red deference (Cr) of Croma components are shown in fig. 4. These components of color image are processed through proposed color image compression method and encoded in to a text file. This file is decompressed through proposed decompression method and again reconstructed into Luma and Croma components. Fig. 5 shows these reconstructed components. Fig. 6 shows a compression between original color image and decompressed color image of girl 1.

![Fig. 3: Original RGB color image of girl 1](image)

![Fig. 4: Luma (Y), Croma Red (Cr) and Croma Blue (Cb) component of girl 1 image before compression](image)

![Fig. 5: Luma (Y), Croma Red (Cr) and Croma Blue (Cb) component of decompressed girl 1 image](image)

![Fig. 6: Comparing original and decompressed color image of girl 1](image)

![Fig. 7: Comparing original and decompressed color image of girl 2](image)

![Fig. 8: Comparing original and decompressed color image of girl 3](image)

![Fig. 9: Comparing original and decompressed color image of couple](image)
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A. Mean Square Error (MSE):
The cumulative squared error between the original color image and decompressed color image is termed as MSE. Lower valued MSE shows less error between original image and decompressed image, and it has the inverse relation with PSNR. In general, it is the average of the square of the difference between the desired response and the actual system output. As a loss function MSE is also called squared error loss. The MSE can be easily represented by equation (10).

\[ \text{MSE} = \frac{1}{m \times n} \sum_{y=1}^{m} \sum_{x=1}^{n} [l(x, y) - l'(x, y)]^2 \] (10)

Here \( l(x, y) \) is the original image and \( l'(x, y) \) is the reconstructed image. Here \( m \) and \( n \) are the dimensions of the image.

B. Peak Signal to Noise Ratio (PSNR):
PSNR is a measurement of the peak error between original color image and decompressed image. PSNR is usually expressed in terms of the logarithmic decibel scale in (dB). Normally, a higher value of PSNR is good because it means that the ratio of signal to noise is higher. Here, a signal represents original color image and noise represents the error in reconstruction. It is the ratio between the maximum possible power of a signal and the power of the corrupting noise. PSNR decreases as the compression ratio increases for an image. The PSNR is defined as:

\[ \text{PSNR} = 10 \times \log_{10} \left( \frac{\text{MAX}_I^2}{\text{MSE}} \right) = 20 \times \log_{10} \left( \frac{\text{MAX}_I}{\text{MSE}} \right) \] (11)

C. Compression Ratio (CR):
Compression ratio (CR) is a measure of the reduction of the detailed coefficient of the data. In the process of image compression, it is important to know how much detailed coefficient one can discard from the input data in order to maintain critical information of the original data. Compression ratio can be expressed as:

\[ \text{CR} = 1 - \frac{\text{Decompressed Image}}{\text{Original Image}} \] (12)

D. Subjective Evaluation Parameter:
The visual perception of the reconstructed image is essential. In some cases the objective quality assessment does not give proper information about the quality of the reconstructed image. In such scenarios, it is important to analyze the reconstructed image using subjective analysis that means by human perceptual system. When the subjective measure is considered, viewers focus on the difference between reconstructed and original image and correlates the differences.

Table-1 shows comparison of mean square error (MSE) between DET, DKT, DCT and proposed hybrid method. Similarly TABLE II shows comparison of peak signal to noise ratio (PSNR) and TABLE III shows comparison of compression ratio (CR) between DET, DKT, DCT and proposed hybrid method. Form this comparison it is found that proposed method has less MSE and higher PSNR as compared then using DWT, CT and DCT individually. From Table III it also clear that proposed hybrid method also compressed more image data as compared to using DWT, CT and DCT individually.

IV. RESULT ANALYSIS
To analyze the proposed method this paper used four parameters these are Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), Compression Ratio (CR) and Subjective Evaluation Parameter.

Fig. 10: Comparing original and decompressed color image of house

Fig. 11: Comparing original and decompressed color image of tree

Fig. 12: Comparing original and decompressed color image of sweet candy 1

Fig. 13: Comparing original and decompressed color image of sweet candy 2

Similar to color image of girl 1, seven other color images girl 2, girl 3, couple, house, tree, sweet candy 1 and sweet candy 2 are also compressed with proposed color image compression method based on hybrid wavelet transform by using DWT, DKT and DCT, and decompressed also. Fig. 7 to 13 shows comparison between their original color image and decompressed color image. By comparing all these images it is found that proposed methods is efficiently lossless compression and decompression method.

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In this paper, one novel concept of the hybrid wavelet transform by using three orthogonal transform is presented, to enhance compression ratio of color image with efficient lossless compression. Here hybrid wavelet transform is generated using Discrete Wavelet Transform, Discrete Kekre Transform and Discrete Cosine Transform together for image compression and decompression as well. From experimental results inference drawn is that the hybrid wavelet transform are better than their respective wavelet transforms. Proposed hybrid wavelet transforms are better in performance as compared to wavelets of orthogonal transform individually. In future various other transform can be considered for hybridizing to generate new hybrid wavelet transforms for particular applications.

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