Lossy Compression in 2D Imageries

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Abstract:
In this paper a compression algorithm has been proposed and its results with respect to Peak Signal-to-Noise Ratio (PSNR) and Mean Square Error (MSE) are compared with Discrete Wavelet Transform (DWT), Discrete Cosine Transform (DCT) and Quad-tree decomposition method. Visual comparison is also carried out between the original and compressed images**.** The proposed algorithm gives the improved results as compared to DCT, DWT and Quad-tree decomposition method. The simulation results have been achieved in MATLAB R2009a.

Index Terms:
DCT, DWT, Quad tree, DFT, PSNR, MSE.

1.0. INTRODUCTION:

Data compression is a technique that transforms the data from one representation to new compressed representation, which contains the same information but with smallest possible size. The size of data is reduced by removing the redundant or excessive information. The data is transmitted and stored at less communication and storage costs.
If a file is compressed by half of its original size, the capacity of the storage is increased twice.

There are two compression techniques named as Lossless and Lossy compression. Lossless compression contributes no loss during compression. Therefore, the reconstructed and the original images are same.
Lossy compression technique provides higher compression ratio as compared to lossless compression. In this method, the compressed image is not same as the original image; there is some amount of information loss in the image. In lossy compression, some information is simply discarded from data and when the data is uncompressed, it is still of acceptable quality.
In this paper a new compression algorithm has been proposed based on discrete wavelet transform and quad tree decomposition. The proposed algorithm has been compared with other common lossy compression standards. The estimation of mean square error (MSE) and peak signal to noise ratio (PSNR) have been carried out in order to determine how closly an image is reproduced with respect to the original image.

2.0. LOSSY COMPRESSION METHODS:

Following are the commonly used Lossy compression methods.
- Using Discrete Cosine Transform (DCT)
- Using Discrete Wavelet Transform (DWT)
- Using Quad Tree Decomposition

2.1. DISCRETE COSINE TRANSFORM:

The Discrete Cosine Transform (DCT) algorithm is well known technique and commonly used for image compression. DCT converts the pixels in an image sets of spatial frequencies. The DCT works by separating images into the parts of different frequencies. The compression occurs in a process called quantization. The less important frequencies are discarded, hence the loss in the information. Then only the most important frequencies remain which are used to retrieve the image. As a result, the reconstructed image is distorted. There are many advantages of DCT as compared to the other techniques.
- The implementation of DCT is not complex.
- DCT packs the most information in fewest coefficients.
- It minimizes the blocking artefact which results when boundaries between sub-images become visible.

The DCT can be extended to the transform the 2D signals or images. This is achieved by calculating the 1D DCT of each of the individual rows of the 2D image and then calculating the 1D DCT of each column of the image. If the size of a 2D image is N × N, then the 2D DCT of the image is given by:

$$Y[j,k] = C[i]C[j]\sum_{a=0}^{N-1}\sum_{b=0}^{M-1} x[a,b]\cos\left(\frac{(2a+1)j\pi}{2N}\right)\cos\frac{(2b+1)k\pi}{2N}$$

------------------------(1)

Where j, k, a, b = 0, 1, 2..., N −1
and

$$C[j] and C[k] = \begin{bmatrix} \sqrt{1/N} & for\ j,k=0 \\ \sqrt{1/N} & for\ j,k=1,2 \ldots\ldots N-1 \end{bmatrix}$$

----------------------------------(2)

The 2D Inverse DCT is defined as

$$x[a,b] = \sum_{j=0}^{N-1}\sum_{k=0}^{N-1} C[j]\, C[k] Y[j,k] \cos\left(\frac{(2a+1)j\pi}{2N}\right) \cos\left(\frac{(2b+1)k\pi}{2N}\right)$$

-------------------------------(3)

The DCT is a real valued transform. It is closely related to the Discrete Fourier Transform (DFT). An N × N DCT of x (n1, n2) can be presented in terms of DFT of its even-symmetric extension, which leads to a fast computational algorithm. There are no artificial discontinuities introduced at the boundaries of the block because the extension process is an even-symmetric. Moreover, the calculation of the DCT needs only real arithmetic. Because of the above mentioned features, the DCT is very popular and used for data compression widely.

The steps for DCT compression and decompression are as follows:-

- Divide the input image into either 8x8 or 16x16 blocks.
- Compute the two-dimensional DCT for each block.
- Quantize, encode and then transmit the DCT coefficients over the channel.
- Decode the quantized DCT coefficients at the receiver.
- Compute the 2D inverse DCT of each block and put the blocks back together into a single image.

The flowchart for DCT compression and decompression is given in figure 1.

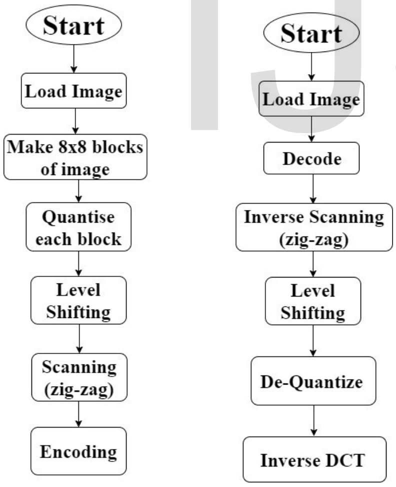

Figure 1: Compression and decompression using DCT

2.2. DISCRETE WAVELET TRANSFORM:

Discrete Wavelet transform (DWT) is one of the most widely used lossy compression method. JPEG 2000 is based on this concept. When DWT is applied to an image, the most prominent information of the image is appeared on high amplitudes and the less prominent information is appeared in very small amplitudes. If we discard these very low amplitudes, which actually causes some data loss, we find the compression of data. The wavelet transform gives good compression ratio as compared to DCT. The reconstructed image quality is also better as compared to DCT.

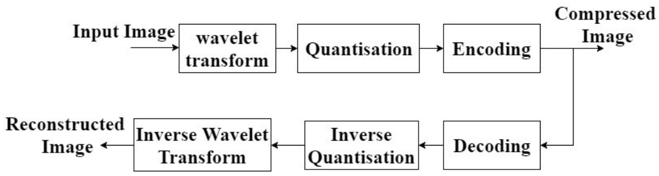

Figure 2: Image Compression and de-compression using wavelet transform

The 2D DWT of an image can be seen as a 1D analysis of a 2D image. It analyses the columns and rows of an image in a separate manner. 1D DWT operates on a 2D image one by one i.e. in one dimension at a time. The first step is to apply the analysis filters on the rows of an image. This operation generate 2 images. First image is a set of coarse row coefficients, and the second is a set of detailed row coefficients. Next step is to apply the analysis filters to the columns of each of the images created in first step. This operation produces 4 images out of these 2 images. These are called sub-bands. The columns and rows which are analyzed with the help of high pass and low pass filter are designated with an H and L respectively. E.g. the image produced by using high pass on rows and low pass on columns is designated as HL sub-band.

All the sub-bands provide different information about the image. The sub-band LL gives the coarse approximation. All the information of high frequency components is removed in LL. In sub-band LH, the information of high frequency components is emphasized along the columns and removed along the rows. As a result an image is created in which vertical edges are emphasized. In sub-band HH the diagonal edges are emphasized and in HL horizontal edges are emphasized. This process is called first level decomposition of image. To compute the second level decomposition, the same process is applied again to the sub-band LL. So, four new images are created from the original image after every level of decomposition. Every new image is of the size one fourth of the original image. The decomposition using DWT is shown in figure 3.

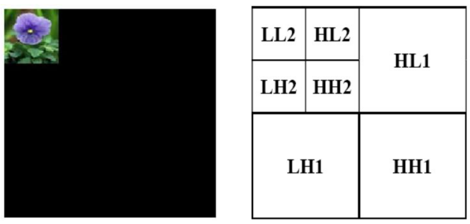

Figure 3: wavelet decomposition of an image

2.3. QUAD-TREE DECOMPOSITION METHOD:

Quadtree technique is widely used for image storage[1]. Quadtree divides a 2D image into four quadrants or blocks. Each block is again divided into four blocks. This process is continued till each block contains only the pixels of single color.

The procedure is explained in following manner.

- First of all we specify the threshold for minimum block size. The minimum block size defines the threshold at which the further decomposition will stop. Apply the quadtree decomposition to the image. This process divides the image into homogeneous and non-homogeneous quadrants. Homogenous quadrants are those quadrants in which all the pixels are of single color only. Figure 4 shows the homogeneous decomposition of an image using quad tree method.

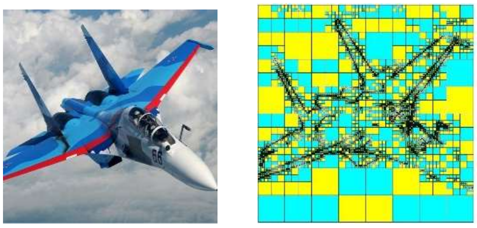

Figure 4: A Quad tree decomposed image

- After that, entropy encode the data of all the homogeneous quadrants. The identification of homogeneous quadrants is done by the size of the quadrant, cartesian coordinates of top left corner of the quadrant and quadrant's luminance. Assign -1's to the luminance values of pixels of homogeneous quadrants. Let this image be K.
- Specify the fitting threshold T. The value of T > 0 for lossy compression. Carryout the scanning of the pixels of K in row wise sequence. The pixels of homogeneous quadrants can be skipped during scanning. The reason is that they have already been addressed by quadtree. Let the number of pixels in the i_{th} row of K are U_i and M_i' (if exclude the pixels of -1 value). Then $|M_i| \geq |M_i'|$.

- The breakpoints can be given to the first and the last pixels of M_i'. M_i' is divided into segments. Calculate the squared distance for each point between M_i' and fitted data. Find the maximum value of fitting threshold T_{max}. If T_{max} > T then remove the k_{th} segment. Replace it with 2 new segments. Add one more breakpoint. Again carryout same process with the new set of breakpoints till maximum threshold between any two points of original and fitted data is less than or equal to threshold. Entropy encode the final set of breakpoints.

2.4. PROPOSED METHOD:

The block diagram for the proposed algorithm is given in figure 4.

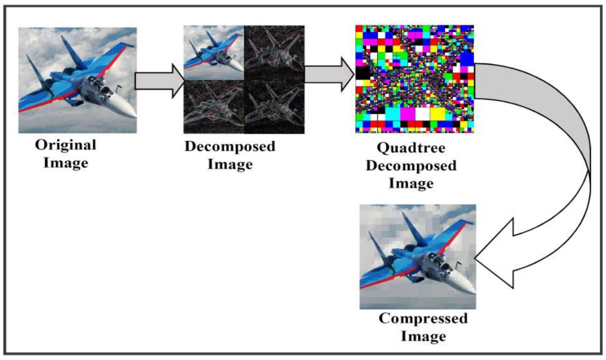

Figure 5: Compression using the proposed algorithm

The procedure is as follows:-

Encoding:

- First level decomposition of the image is carried out. Four new images are created from the original image in this process. The size of these new images is reduced to one fourth of the original size. The new images LL, LH, HL, and HH are created according to the low-pass or high-pass filter which is applied to the original image in the vertical and horizontal directions.
- The LL image which is a reduced but approximate version of the original image, is chosen because most of the details of original image is retained in this image.If size of LL is not a power of 2 then pad the image with -1's. For example, if the size of LL is 249×228 then padding will make the size 256×256. It is named as LL1.
- Specify the threshold of minimum block size. Here we specify the threshold as 4. So the minimum block size in our case is 4×4. Then the quadtree decomposition to the LL1 is applied. The homogeneous quadrants are Entropy encoded. Each homogeneous quadrants is identified by the size of the quadrant, Cartesian Coordinates of top left corner and luminance of the quadrant.
- Then we replace the luminance values of pixels of homogeneous quadrants in LL1 with -1's. We now name it as LL2. Specify threshold of fitting. We define it as T. The value of threshold is more than zero for lossy compression.
- We scan the pixels of LL2 in row wise manner. Here we skip the homogeneous quadrants during scanning. We assume M_i pixels in the i_{th} row of LL2 and M_i' pixels in the i_{th} row of LL2 but excluding the pixels of -1's value. Here $|M_i| \geq |M_i'|$. M_i' consists of luminance values of all the pixels in i_{th} row. Every element of M_i' is taken as a point in 1D Euclidean space. Also the first and the last pixels of M_i' are taken as breakpoints.
- We divide the M_i' into different segments which are nothing but a set of all pixels between two alongside breakpoints. Further we apply the fitting process to each segment by taking every pair of alongside breakpoints as the top and the end point of parametric line and get

the *fitted data*. Here we make an assumption that U_i is the set of points in the fitted data.

- As we have M_i' and U_i data available, we calculate the squared distance between each point of U_i and M_i' respectively. Then after finding the value of T_{max} we calculate the point of maximum squared distance and denote it by z. If $T_{max} > T$, we replace the k_{th} segment by two new segments at z. Then we add a new breakpoint bp_{new} in the set of breakpoints.
- Again we repeat the fitting process by taking the new set of breakpoints. This is done till the value of T_{max} between any two points of original and fitted data is less than or equal to threshold T. Finally we carry out the Entropy encoding of the final set of breakpoints and interpolation points between them.

Decoding:

- First of all we create an empty image (all the pixels of 0 values) X of the size of the LL1. Then we assign -1's to every pixel of homogeneous quadrants of X. Then parametric line interpolation is performed as per the equation (4) and the fitted data is obtained.

$s_j(\tau) = (1-\tau)\, r_j + \tau .\, r_{j+1},\ \tau \in [0, 1],\ 1 \le j \le k,$ ---------(4)

Where $s_j(\tau)$ is an interpolated point between control points r_j and r_{J+1} at τ and k is the number of interpolated points.

- We fill the image X with U_{pl} skipping pixels of -1's values. This gives us the portion of image decoded by the parametric line. Fill the homogeneous quadrants of image X using actual values of homogeneous quadrants. Finally we trim the image X into the size of original image. This is our decoded or reconstructed image.

3.0. Quality MEASURES:

The compression Techniques commonly used for Lossy compression results in some degradation of the reconstructed image. A commonly used measure for the reconstructed image quality is the Mean Square Error (MSE). If an image size is N x M, then the MSE is given by [21]:-

$$MSE = \frac{1}{N.M}\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}(A(i,j)-B(i,j))^2$$

--------------------------------(5)

Where *A (i, j)* is the original image information and *B(i, j)* is the compressed image information. Signal-to-Noise Ratio (SNR) is commonly used in the signal processing because it relates the noise power to signal power. It is more meaningful as it gives 0 dB when signal and noise power are equal. The SNR is given by [22]:-

$$SNR = 10.\log\left\{\frac{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}A(i,j)^2}{\sum_{i=0}^{N-1}\sum_{j=0}^{M-1}[A(i,j)-B(i,j)]^2}\right\}$$

-------------------------------------(6)

Peak signal-to-noise ratio (PSNR) is another quantitative measure of the reconstructed image. The PSNR for gray scale images is given by

$$PSNR = 10\,.\log(\frac{255^3}{MSE})$$

-----------------------------(7)

The PSNR for colored RGB images is given by

$$PSNR = 10\,.\log(\frac{255^3.3}{MSE(R).+MSE(G)+MSE(B)})$$

---------------------------------(8)

4.0. RESULTS:

Five different types of images named as Flower1, Flower2, Tank1, Tank2 and Sukh have been taken for experiments. The images are chosen such that the comparison parameters may be compared optimally. DCT, DWT, Q-tree method and proposed algorithm have been applied on the above images. The simulation results are achieved using MATLAB R2009a. The compression results are tabulated in table 1.

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Table1: Image compression using various methods

	Images				
	Flower1	**Flower2**	**Tank1**	**Tank2**	**Sukh**
Original					
DCT					
Wavelet					
Quad tree					
Proposed Algorithm					

The MSE and the PSNR values obtained using various Lossy Compression methods are given in Table 2 and table 3 respectively.

For example, in the case of the image 'Flower1', we see from table 2 that the MSE values for DCT, Wavelet and Q-tree decomposition methods are 257.57, 183.21 and 69.79 respectively. When apply our proposed algorithm, the MSE comes down to 66.28 which is an improved value over other methods. The similar results are obtained for other images in the table 1.

Table 2: Comparison chart for MSE values

	Flower1	Flower2	Tank1	Tank2	Sukh
DCT	147.57	141.69	285.79	231.22	164.90
wavelet	123.21	175.66	242.84	135.84	102.98
Q-Tree	97.79	137.33	136.90	193.47	85.53
Proposed	66.28	93.79	196.43	121.51	108.58

Table 3: Comparison chart for PSNR values (in dB)

	Flower1	Flower2	Tank1	Tank2	Sukh
DCT	23.79	24.39	19.54	22.26	22.78
wavelet	25.27	25.46	27.56	24.64	26.07
Q-Tree	24.69	25.41	20.46	25.11	24.62
Proposed	29.69	29.85	24.79	27.06	26.48

In the similar way, in the case of the image 'Flower1', we see from table 3 that the PSNR values for DCT, Wavelet and Q-tree decomposition methods are 28.79, 30.27 and 26.69 dB respectively. When apply our proposed algorithm, the PSNR is 34.69 dB which is an improved result over other methods.
The similar results are obtained for other images in the table 1.
The same results are represented in the form of bar charts in Figure 6 and Figure 7 respectively.

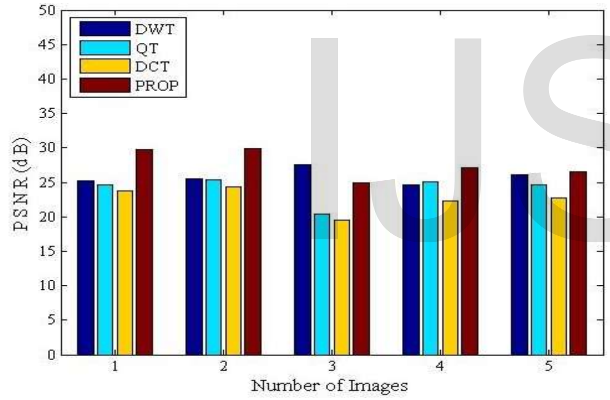

Figure 6: Bar chart representation of PSNR values

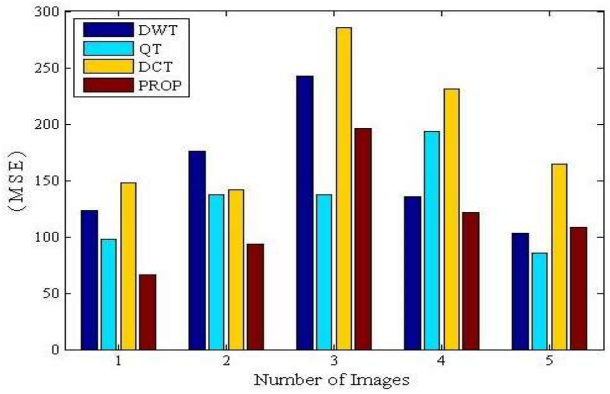

Figure 7: Bar chart representation of MSE values

5.0. CONCLUSION:

The effectiveness of the proposed algorithm is achieved by comparing the performance with respect to DCT, DWT and Q-tree method. The simulation results are examined using MATLAB R2009a. By analyzing the results, it is concluded that the proposed algorithm has the improved compression performance over the existing ones. It has superior PSNR values and less MSE values as compared to the existing methods.

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