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Low-Complexity Image Compression Scheme Using Discrete Tchebichef Transformation

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Abstract

In recent times, the advancements in the field of effective image compression lead to the development of potential applications. The goal is to reduce the memory requirements, increasing speed and space domain processes. Since transmission of images having suitable computational resources, different image compression techniques have been proposed in this paper. The existing image compression techniques are not committing the space domain process capabilities. In this article, we propose a new high energy compaction and low-complexity image compression scheme using Discrete Tchebichef Transformation (DTT) algorithm. The DTT algorithm performs the space reduction operation. The proposed DTT algorithm increases the compression performance and decreases the energy utilization. Comparing the performance of Discrete Cosine Transform (DCT), based on transformation techniques with the proposed DTT, it has been proved that the DTT is the optimal image compression technique.
Keywords: Image compression, Tchebichef Polynomials, DCT and DTT.

1. Introduction

Digital images processing occurring large number of bits processing to represent them and in their canonical form of representation and also contains significant amount of redundancy. Image compression techniques reduce the number of bits that are required to represent an image by taking advantage of these redundancies. Many techniques have been developed to reduce the redundancy. In the past, many efforts have been made and implemented for the secure transmission of medical images through web by compressing the images using Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) methods. The images must be transmitted in the shortest possible time. A lot of researches have been done previously and made available for achieving image transmission through web [1]. Based on various review of literature, some of the methods clearly defined, image quality is tarnished because the transformation process includes blocking artifacts at higher compression ratios [2], image quality is somewhat sacrificed for low quantization levels [3] and organized using Picture Archiving and Communication Systems (PACS) data model for distribution to 10 – 20 work stations using image archiving technique [4].

2. Literature Review

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In the process of Image compression schemes using DCT, JPEG and DWT methods, the blurring effect in raw images and the reduction in image resolution with high MSE and low PSNR are the major drawbacks [5]-[10]. Among the image compression techniques available, transform coding is the preferred method. Transform coefficients are used to maximize compression. For lossless compression, the coefficients do not allow any loss of information. The DCT is an example of transform coding. The current JPEG standard uses the DCT as its basis. The DC relocates the highest energies to the upper left corner of the image. The lesser energy or information is relocated into other areas [11]. The DCT acts fast and it can be quickly calculated at its best when used for images with smooth edges like photos with human subjects. The Inverse Discrete Cosine Transform (IDCT) can be used to retrieve the image from its transform representation [12].

Due to the increase in demands for transmission of images in computer and mobile environments, the research in the field of image compression has increased significantly. The recent image compression research includes a crucial role in digital image processing; it is also very essential research for efficient image transmission and its storage. When one computes the number of bits per image resulting from typical sampling rates and quantization methods, it is found that the importance of image compression is realised. Therefore, development of efficient techniques for image compression has become necessary. Raid et al proposed lossy image compression using DCT; it covers JPEG image compression algorithm is used for colouring (full-colour) [13].

The DCT is a best image transformation technique for converting the processing of signal stages into elementary frequency stages. Some functions have been developed to compute the DCT and to compress images [14]. The proposed algorithm significantly raises the PSNR and minimizes the MSE at lower iterations, Compression Ratio values increases at higher level than the quality of image also higher. The CPU processing time for processing of image compression is calculated to find the complexity of algorithm [15]. Hybrid compression technique is proposing for imaging discrete cosine transform and singular value decomposition. In this review, the author proposed proper threshold value and the transformed information using DCT and SVD can be truncated. Using these results of the image transformation an effort is higher compression ratio [20]. Tchebichef moment approaches to be used a most recent moment function which is used to attract the interest. Discrete orthogonal Tchebichef Moment explains an efficient image compression. [21].

The image reconstruction accuracy was analysed when using different orthogonal basis functions as the kernel for a reversible image transform. The results are found that the DCT provides the greatest energy compactness properties for continuous tone images (such as photographs), among the various transformations like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DTT), Haar Transform, and Walsh-Hadamard Transforms (WHT). For images demonstrating rapid gradient variation the Haar Transform performs significantly better than any of the other transforms although its performance on continuous tone images is substantially worse than either DCT or DWT [22].

In image transformation and compression techniques most of the researchers using moment functions, based on Tchebichef polynomials techniques have been proposed. The functions mainly used robust feature representation for recognition of various task. The system explains different possibility of orthonormal using Tchebichef polynomials techniques for image transformation and compression. In this paper author clearly indicates, the Tchebichef transform is a higher PSNR value compared to the CT [24].

3. Proposed Work

3.1 Discrete Cosine Transformation (DCT)

Among all the image compression techniques available, transform coding is the preferred method. The image compression is a major research area, but it is not an easy task for doing the research. Transform techniques is simply doing the compression methodology of the particular images in the region of particular frequency domain. Transform coefficients are used to maximize compression. For lossless compression, the coefficients should not allow any loss of information. The DCT is an example of transform coding. The JPEG standard uses the DCT for its method. The DC relocates the highest energies to the upper left corner of the image. The lesser energy or information is relocated into other areas [25].

Computes the i, jth entry of the DCT of an image.

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

$$C(u) = \begin{Bmatrix} \frac{1}{\sqrt{2}} \; if\ u = 0 \\ 1 \quad if\ u = 0 \end{Bmatrix} \qquad (2)$$

Where p(x, y) is the element of the image represented by the p. N is the size of the particular block of DCT is done. The equation is used to complete the entry (i, j) of the transformed image process from the pixel values of the corresponding original image. In DCT the standard 8 x 8 block the compression uses, N equals 8 and x and y range from 0 to 7. The equation D(i, j) is presented in Equation (3).

$$D(i,j) = \frac{1}{4} C(i)C(j) \sum_{x=0}^{7} \sum_{y=0}^{7} p(x,y)\, cos\left[\frac{(2x+1)i\pi}{16}\right]\; cos\left[\frac{(2y+1)j\pi}{16}\right] \qquad (3)$$

Because the DCT uses Cosine functions. The resulting matrix depends on the horizontal, diagonal, and vertical frequencies [26]

3.2 Discrete Tchebichef Transform (DTT)

DTT is a commonly used unexploited orthogonal transform and it’s used to show several valuable parameters like energy compaction and recursive computation. DTT is built on discrete Tchebichef polynomials (DTP), and DTP is a class of hyper geometric orthogonal polynomials [27] [28]. The n-th order scaled DTP is defined as follows.

$$\tilde{t}_n(x) = \frac{t_n(x)}{\sqrt{\rho(n,N)}} \qquad (4)$$

Where $t_n(x)$ is the original DTP

$$t_n(x) = n! \sum_{k=0}^{n} (-1)^{n-k} \binom{N-1-k}{n-k} \binom{n+k}{n} \binom{x}{k} \qquad (5)$$

DTT can be written as

$$y(n,m) = \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} \tilde{t}_n(i)\, \tilde{t}_m(j)\, X(i,j) \qquad (6)$$

Consequently, the inverse DTT is defined as

$$X(i,j) = \sum_{n=0}^{N-1}\sum_{m=0}^{N-1} Y(n,m)\, \tilde{t}_n(i)\, \tilde{t}_m(j) \qquad (7)$$

with i, n = 0,1,2, … ,N -1and j, m = 0,1,2, … ,M -1.
Similarly, the forward DTT and its inverse version defined in Eqs. (6), (7) can also be written in form of matrix as

$$Y = A.X.A^T \text{ and } X = A^T.Y.A \qquad (8)$$

Where A^T=A^{-1} and $A(i,j)$=$\tilde{t}_i(j)$

4. Performance Parameters

Different parameters are used for the performance evaluation in image compression techniques to measure the quality and efficiency of proposed system. The proposed system taking consideration into various performance evaluation matrices namely Compression Ratio (CR), Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Compression Time (CT).

4.1 Compression Ratio

Compression algorithm is used to compressing the images for the given set of data is to look into the consideration for the ratio of bits required to indicate the data before compressing the images into the number of bits movements for required the data after compression is completed. This ratio is called CR and the compressed image from the original by Equation 9.

$$CR = \frac{I_S}{J_S} \qquad (9)$$

Where I_s is the size (in terms of bits) of the uncompressed image I, and J_s is the size of the compressed image J. Compression ratio values may vary ranging from 0.3 to 98.2.

4.2 Mean Square Error

The Mean Square Error (MSE) is an objective dissimilarity measure which gives the extent of distortion produced by the decoding algorithm. MSE of the decoded image defines the amount by which the decoded image differs from the original image. The value of MSE will be greater than or equal to 0. The MSE of the decoded image, I′ from original image is defined in Equation 10.

$$\text{MSE} = \frac{1}{m*n}\left(\sum_{i=0}^{m-1}\sum_{i=0}^{n-1}\left(I_{i,j} - I'_{i,j}\right)^2\right) \qquad (10)$$

Where, $m\times n$ - is the size of the image.

4.3 Peak Signal-to-Noise Ratio

The Peak Signal-to-Noise Ratio (PSNR) is an important metric to measure the objective dissimilarity of the decoded image from the original image. The PSNR accounts on the signal retaining capacity of the decoding algorithm and is the ratio between the maximum possible powers of the image (255 levels). Because many signals have a very wide dynamic range, PSNR is expressed in terms of the logarithmic decibel scale.

$$10\ log_{10}\left(\frac{255^2}{MSE}\right) db \qquad (11)$$

Where 255 is the maximum pixel (signal) value of the image (when B bits are used to represent a pixel, then this maximum value will be $2^B - 1$) with a pixel represented by 8 bits. PSNR values in image compression are between 20 and 50 dB. A high PSNR means that the reconstructed image has more similar to original image. Most of the researches for proved the transmission quality loss between 20 dB to 25 dB.

For colour images with three RGB levels, the PSNR is the same except that the MSE is the sum over all the squared value differences divided by image size and by three. i.e. the MSE of colour image is defined as follows.

$$MSE = \frac{1}{3mn}\left(\sum_{i=1}^{3}\sum_{j=1}^{m}\sum_{k=1}^{n}\left(I_{i,j,k} - I'_{i,j,k}\right)^2\right) \qquad (12)$$

Where , $m \times n$ is the size of the image.

5. Results and Analysis

The proposed system has been considered 10 groups of images for experiment namely animal, birds, face, historical places, naturals, objects, flowers, vehicles, buildings and fruits and vegetables etc each group contain 10 images. In these experiments, the proposed system compresses 100 images using both DCT and DTT transforms. In this paper 25 images which are 5 sample images from 5 groups were considered. The experimental results of different parameters namely CR, MSE, PSNR (db) and CT (seconds) applied on the images are shown in the table 1 to table 5.

Table 1 Compression of Animals image using DCT and DTT

Animal Image	CR		MSE		PSNR (db)		CT (sec)	
	DCT	DTT	DCT	DTT	DCT	DTT	DCT	DTT
A1	2	3	52.38	46.45	28.93	31.46	7.11	5.44
A2	4	4	39.44	37.21	22.17	22.42	4.49	6.67
A3	3	5	90.83	87.67	28.54	28.70	1.02	2.75
A4	3	4	21.39	18.94	24.82	25.35	6.46	2.33
A5	5	6	65.47	62.72	29.97	30.15	7.65	2.64
Total	17	22	269.51	252.99	134.43	138.08	26.73	19.83
Average	3.40	4.40	53.90	50.60	26.89	27.62	5.35	3.97

The experimental input images for the DCT and DTT methods are, some set of images with various image sizes (800*600,512*512,336*336,256*256,120*80) and formats like bmp, png, tiff, jpeg, are shown in the Fig (1a) to 5(a). From the 25 sample images 18 images nearly 72% of data set is jpeg with same size 120*80, for this reason CR value is increased as low.

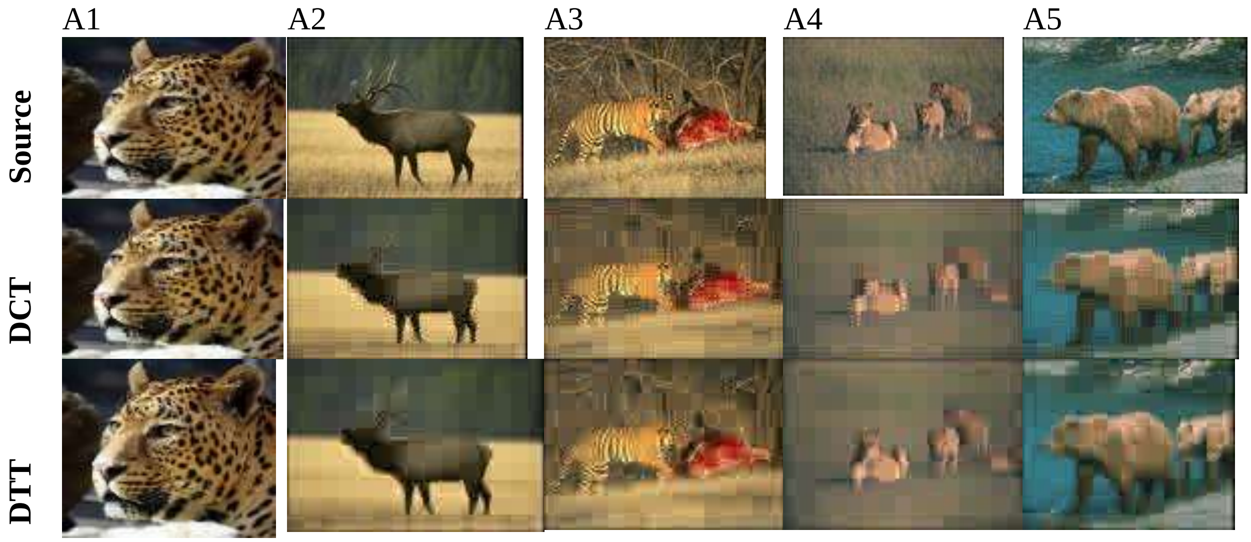

Fig. 1(a) Comparison between DCT and DTT based on compressed Animals images

Fig. 1(b) Comparison between DCT and DTT based on CR and MSE for Animals images

Table 2 Compression of Birds image using DCT and DTT

Birds Image	CR		MSE		PSNR (db)		CT (sec)	
	DCT	DTT	DCT	DTT	DCT	DTT	DCT	DTT
B1	4	5	17.17	13.39	27.78	28.88	2.70	4.71
B2	3	3	45.27	41.01	26.27	27.01	2.85	3.42
B3	1	2	38.17	36.84	29.31	29.46	4.84	2.42
B4	5	6	21.21	18.05	28.86	29.56	3.33	2.39
B5	2	3	28.88	25.16	26.52	27.12	3.13	2.59

Total	15	19	150.70	134.45	138.74	142.03	16.85	15.53
Average	3.00	3.80	30.14	26.89	27.75	28.41	3.37	3.11

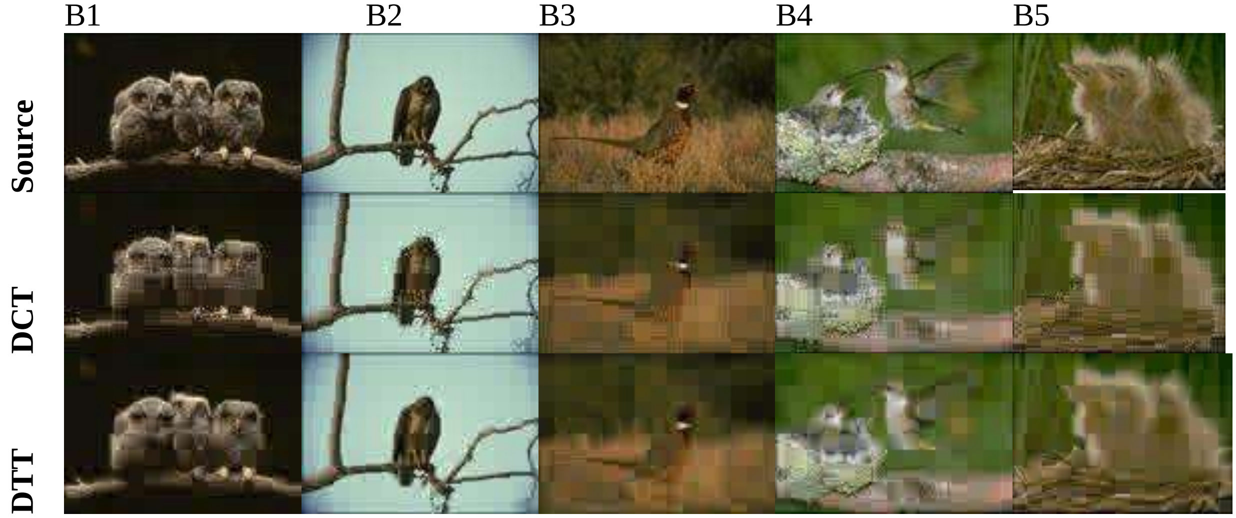

Fig. 2(a) Comparison between DCT and DTT based on compressed Birds images

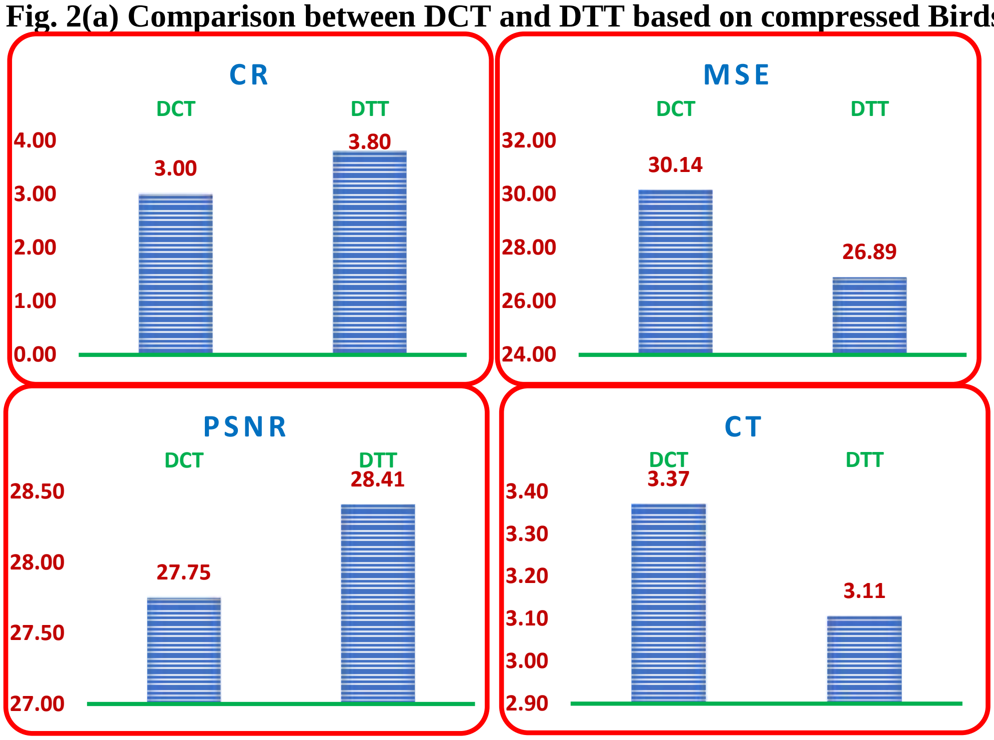

Fig. 2(b) Comparison between DCT and DTT based on CR and MSE for Birds images

Table 3 Compression of Historicals image using DCT and DTT

Historical Images	CR		MSE		PSNR (db)		CT (sec)	
	DCT	DTT	DCT	DTT	DCT	DTT	DCT	DTT
H1	3	4	56.48	54.22	30.61	30.78	3.91	4.28
H2	3	5	36.26	31.63	30.53	33.12	2.59	2.44

H3	5	7	18.36	15.88	32.48	36.12	2.76	2.41
H4	7	8	21.91	19.78	34.72	35.16	3.36	2.46
H5	6	8	69.52	66.39	29.70	29.90	5.58	2.67
Total	24	32	202.53	187.90	158.04	165.08	18.20	14.26
Average	4.80	6.40	40.51	37.58	31.61	33.02	3.64	2.85

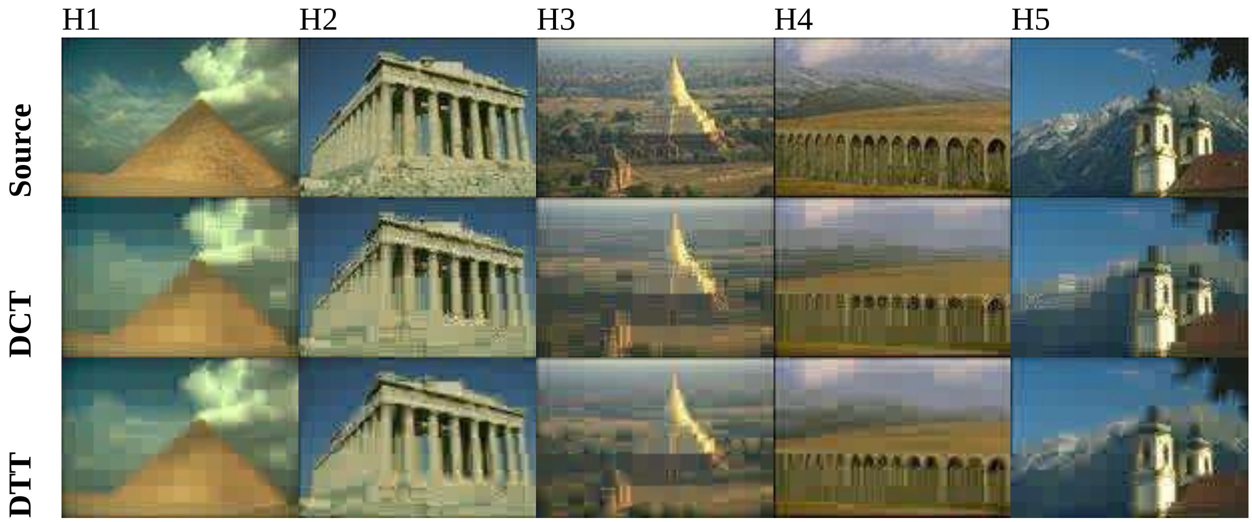

Fig. 3(a) Comparison between DCT and DTT based on compressed Historical images

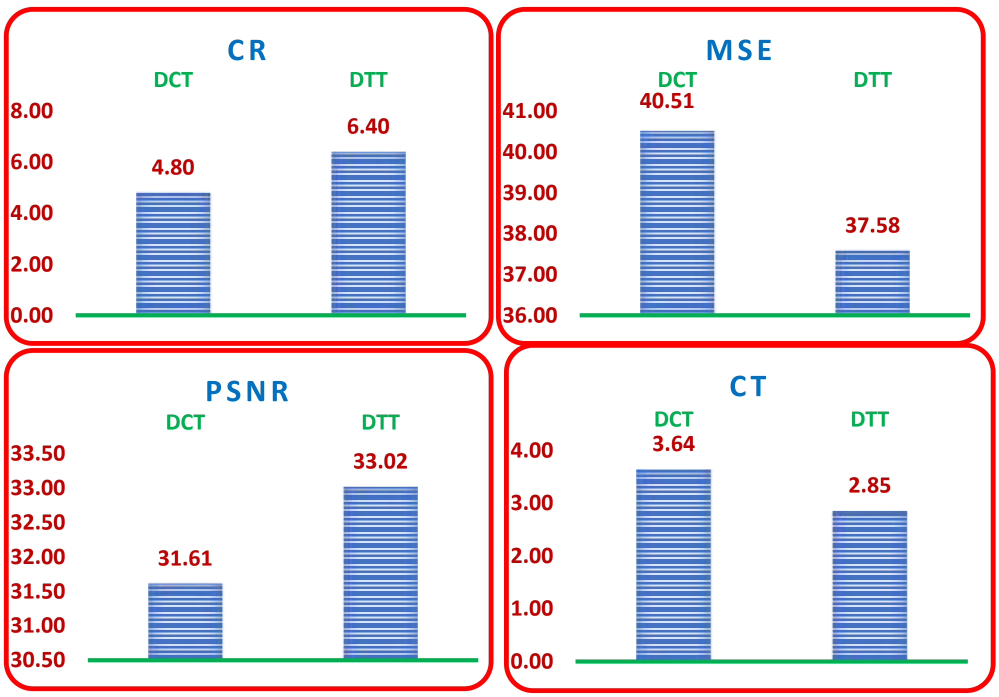

Fig. 3(b) Comparison between DCT and DTT based on CR and MSE for Historical images

Table 4 Compression of Naturals image using DCT and DTT

Natural Images	CR		MSE		PSNR (db)		CT (sec)	
	DCT	DTT	DCT	DTT	DCT	DTT	DCT	DTT
N1	2	2.5	86.20	78.73	28.77	29.16	7.04	4.25
N2	3	5	11.45	10.84	27.53	27.77	3.76	3.89
N3	5	5	85.52	83.15	28.81	28.93	2.68	3.03
N4	4	7	27.81	20.88	33.68	34.93	2.76	3.33
N5	2	4	15.22	14.75	26.13	26.44	2.76	3.12
Total	16	23.5	226.20	208.35	144.92	147.23	19.00	17.62
Average	3.20	4.70	45.24	41.67	28.98	29.45	3.80	3.52

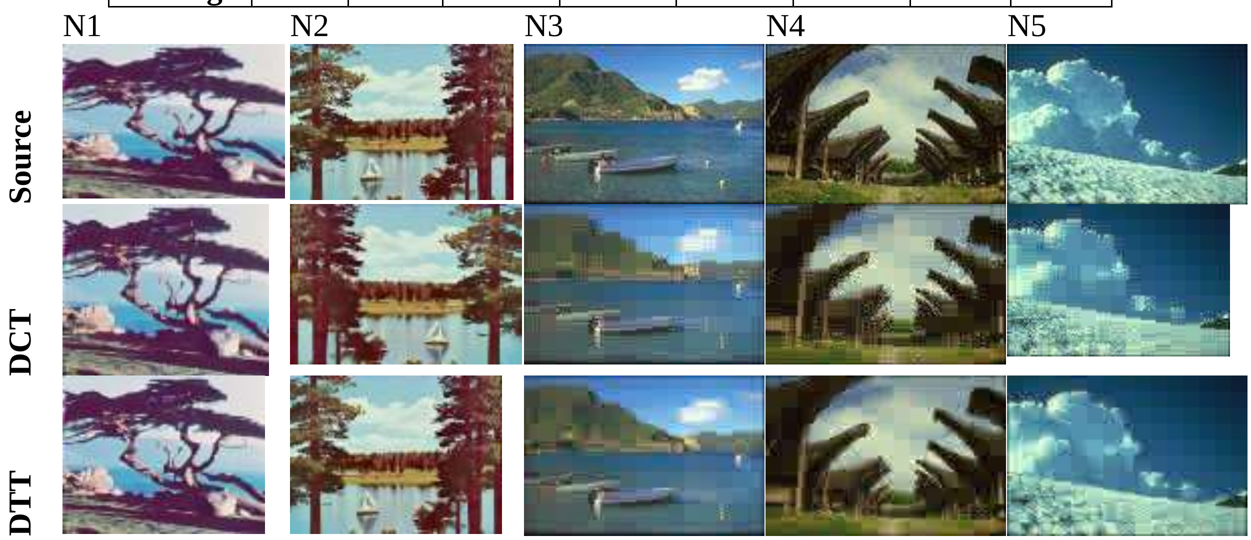

Fig. 4(a) Comparison between DCT and DTT based on compressed Natural images

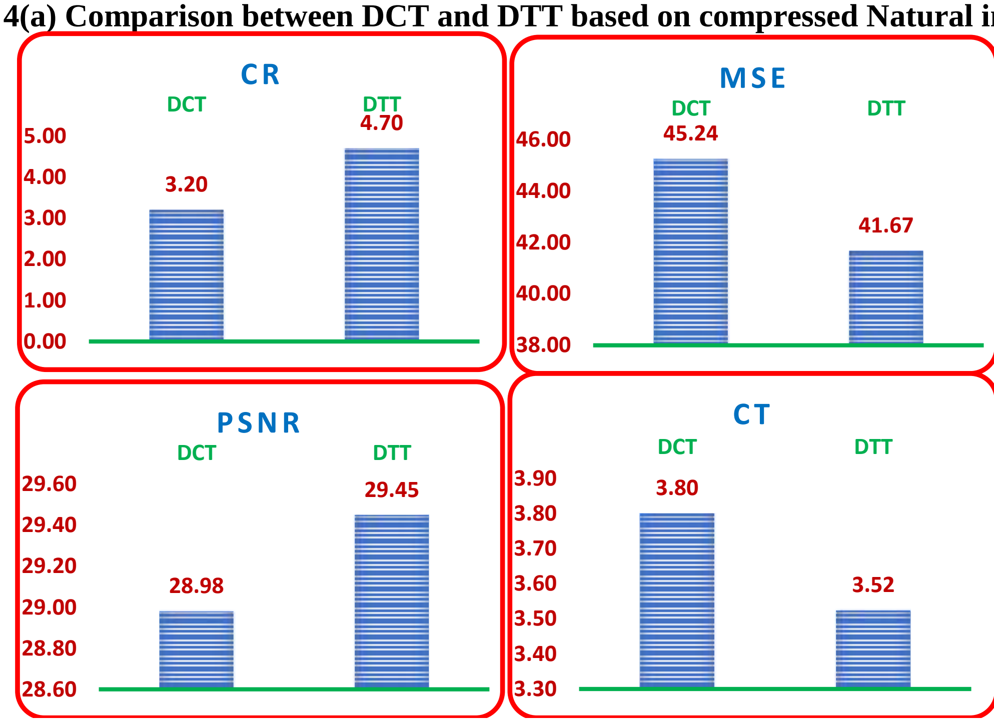

Fig. 4(b) Comparison between DCT and DTT based on CR and MSE for Natural images

Table 5 Compression of Fruits and Vegetables image using DCT and DTT

Fruits and Veigetables	CR		MSE		PSNR (db)		CT (sec)	
	DCT	DTT	DCT	DTT	DCT	DTT	DCT	DTT
V1	5	7	33.72	33.51	32.08	32.87	6.23	8.10
V2	3	3.5	99.62	97.42	28.14	28.24	3.40	3.21
V3	6	7	12.02	11.82	27.03	27.43	5.47	3.22
V4	5	6	46.75	46.70	21.43	21.43	4.49	3.36
V5	2	4	55.77	51.06	28.09	28.98	3.33	3.34
Total	21	27.5	247.88	240.51	136.77	138.95	22.92	21.23
Average	4.20	5.50	49.58	48.10	27.35	27.79	4.58	4.25

Fig. 5(a) Comparison between DCT and DTT based on compressed Fruits and Vegetables images

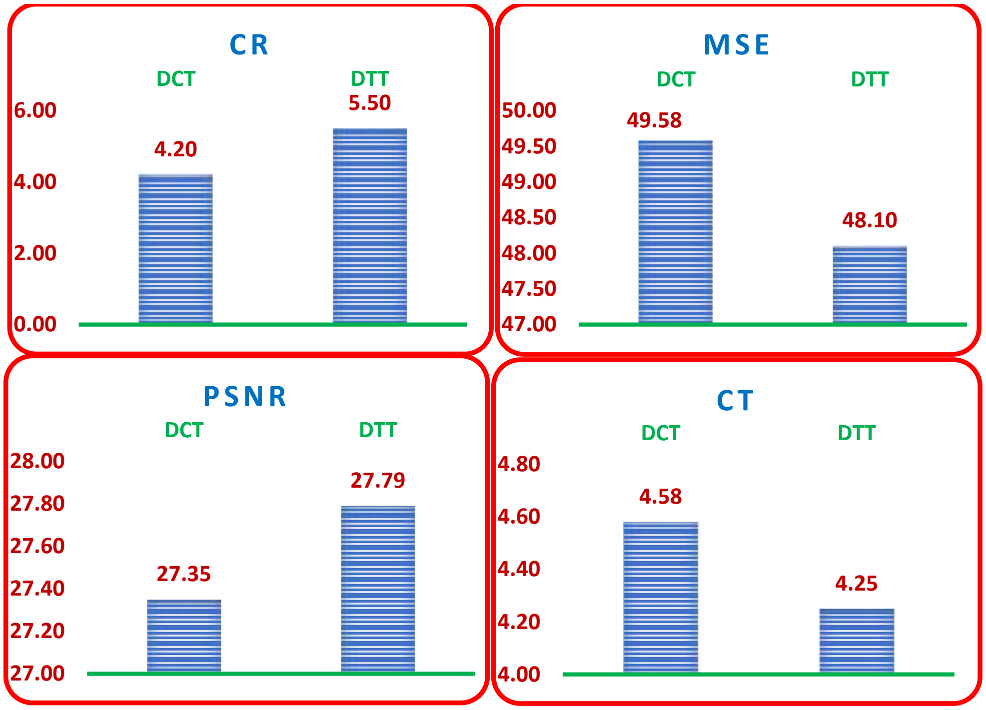

Fig. 5(b) Comparison between DCT and DTT based on CR and MSE for Fruits and Vegetables images

6. Conclusion

The parameters of Compression Ratio (CR), Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and Computed Time (CT) are taken into consideration for the evaluation of image compression. Five different groups of sample images namely Animals, Birds, Historical places, Naturals, Fruits and Vegetables images with various sizes likely (512*512,256*256,120*80) five images were taken for the analysis using DCT and DTT methods. It is easily known from the experimental results, DTT compression ratio varies from 0.8 to 1.6 for all set of images. Bird image groups contain low compression ratio and the Historical image group achieved maximum due to the different size and format of the image. It is intended that the compression ratio of DTT is satisfactory, mean square error is lesser than DCT in which values range from 11 to 98 and PSNR values ranging from 26.88 to 33.01 are achieved for all possible set of images which are shown in from Table 1 to Table 5. The figures from (1a) to 5(b) show good visual quality in the compressed images which is achieved using the DTT method compared to DCT. Finally, it is inferred that new DTT transformation is the best transformation method compared to DCT transformation method based on the results of performance parameters like CR, MSE, PSNR and CT.

7. References

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