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DCT SVD Based Hybrid Transform Coding for Image Compression

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Abstract—Image compression is one of the existing research areas in the field of multimedia. In this paper we are proposing a novel scheme for image compression using discrete cosine transform and singular value decomposition. It is proposed that discrete cosine transform of the image can be truncated. For this truncated discrete cosine transformed matrix, singular value decomposition is applied. The Singular Value Decomposed matrices can be truncated and the truncated matrices are multiplied and transmitted. The effort is made to compare the techniques with only DCT in terms of PSNR, Compression Ratio and computational complexity. The experiment is done for different set of file formats.

Keywords- *DCT-Discrete Cosine Transform, SVD-Singular Value Decomposition, MSE-Mean Squared Error, PSNR-Peak Signal to Noise Ratio, CR-Compression Ratio*

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I. INTRODUCTION

Image compression plays a vital role in the field of Multimedia. There are number of compression techniques available. Compression techniques may be lossless compression techniques and lossy compression techniques. In lossless compression techniques the quality of the reconstructed image is very good, but the price paid for it is the excessive transmission bandwidth. In lossy compression technique the transmission bandwidth is reduced but acceptable quality of the reconstructed image is obtained. In this paper we are proposing a lossy image compression technique using Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD).

This paper consists of seven sections. The first section deals with the introduction, the second section deals with literature survey, the third section deals with the methodology, the fourth section deals with implementation, the fifth section deals with the results and discussions , the sixth section deals with the scope for further enhancement and the seventh section deals with the references.

II. LITERATURE SURVEY

There are different contributions to the above discussed problem. Few papers are discussed in this section.

Raghavendra.M.J [1] and others have worked on Image Compression using DCT and SVD to achieve image compression. Prasantha.H.S and others [2] have worked on image compression using SVD. S.Sridhar and others [3] have worked on image compression using different types of wavelets. T.D.Khadatre and others [4] have worked on compression of image using vector quantization and wavelet transform. Athira.M.S and others [5] have worked on image compression using artificial neural networks. Pallavi and others [6] have worked on image compression using Wavelets and Huffman Coding. E.Praveen Kumar and others [7] have worked on image compression using multiwavelet transforms. D.Vishnuvardhan and others [8] have worked on image compression using curvelets.

Birendrakumar Patel and others [9] have worked on image compression using Artificial Neural Networks. Sumegha.Y and others [10] have worked on fractal image compression using Discrete Cosine Transform and Discrete Wavelet Transform. Rowayda A.S [11] worked on SVD for image processing applications. K.R.Rao [12] and others have worked on DCT.

III. METHODOLOGY

In the proposed scheme, discrete cosine transform and singular value decomposition are used to compress the image data.

Discrete Cosine Transform

Discrete Cosine transform is consists of real coefficients. It is derived from discrete Fourier transform. It is computationally faster than discrete Fourier transform.DCT provides energy compaction. In the transformed domain low frequency coefficients have larger magnitude. High frequency coefficients have smaller magnitude.

The formula of 2-dimensional DCT for the input function f(x,y)is as follows.

$$A(u,v) = B(u)C(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\left\{\frac{(2x+1)u\pi}{2N}\right\}\cos\left\{\frac{(2y+1)v\pi}{2N}\right\} \quad (1)$$

Where u =0, 1, 2...N-1, v=0, 1, 2...N-1, f(x, y) =input function

The inverse 2-dimensional DCT formula is as follows

$$f(x,y) = \sum_{u=0}^{N-1}\sum_{v=0}^{N-1} B(u)C(v)A(u,v)\cos\left\{\frac{(2x+1)u\pi}{2N}\right\}\cos\left\{\frac{(2y+1)v\pi}{2N}\right\} \quad (2)$$

Where B (u) =$\sqrt{1/N}$ for u=0, B (u) =$\sqrt{2/N}$ for u=1, 2 ...N-1

Similarly C (v) =$\sqrt{1/N}$ for v=0, C (v) =$\sqrt{2/N}$ for v=1, 2 ...N-1

Singular Value Decomposition

Singular value decomposition, decomposes the given data input matrix into three matrices, namely “U”, “S” and “V”. If the input data matrix is of the order m×n, then decomposed matrices “U” is of the order m×m , “S” is of the order m×n and “V” is of the order n×n. The singular value decomposition finds the eigen values of the input data matrix. The matrix “S ” contains all the elements as zero except the elements on the diagonal of the matrix. If s1,s2,s3....sn are the diagonal elements, it has the property $s1 \geq s2 \geq s3 \geq \cdots \geq sn$. The stretch of these elements gives rise to rank of the SVD

In this paper an effort is made to compress the image using hybrid compression technique. The block diagrams of the proposed two systems are as follows.

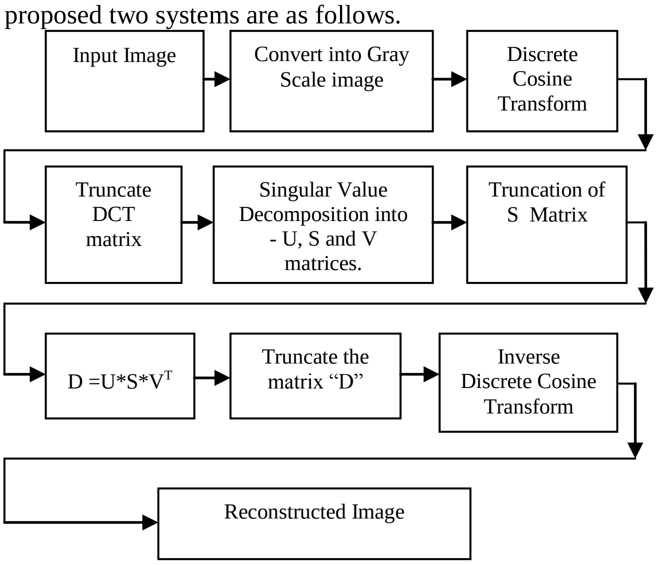

Figure1. Block diagram of the image compression using DCT-SVD method.

Fig.1 shows the block diagram of the image compression using DCT-SVD. In this method, the image is taken at the input. The first stage is to convert the given image into gray scale format. If the image is already in the gray scale format, it is retained as it is. Then, Discrete Cosine Transform (DCT) is applied to the gray scale image. Now for this DCT matrix threshold "r" is applied. That means all those coefficients less than "r" are neglected. Now, this truncated DCT matrix is decomposed using Singular Value Decomposition (SVD). The output of the SVD results in three matrices "U", "S" and "V". In this, Threshold for "S" matrix is fixed as 200.That means all those coefficients less than 200 in "S" matrix are neglected. This threshold for "S" matrix is fixed by empirically. The experiments are conducted for different threshold values, but this threshold is found to be optimum. Now, "U" matrix, truncated "S" matrix and "V^T" matrix are multiplied to give $D=U*S*V^T$. Again for this "D" matrix, the same threshold "r" is applied. That means all those coefficients less than "r" are neglected. Then, it gives the truncated "D" matrix. Then in this truncated "D" matrix, non zero elements are assumed to be transmitted. At the receiver side inverse discrete cosine transform is applied for "D" matrix to obtain the reconstructed image. Then reconstructed image is compared with different parameters. The computation time taken for Discrete Cosine Transform, Truncation of DCT, SVD, truncation of "S" matrix and multiplication of $D=U*S*V^T$ and Inverse Discrete Cosine Transform is measured.

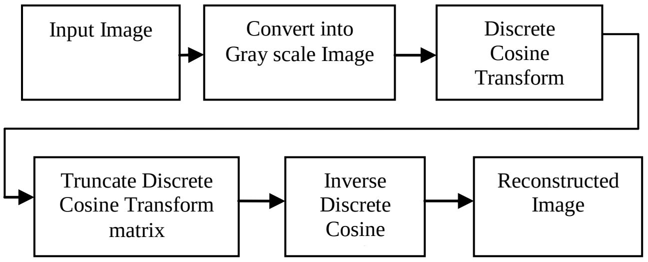

Figure 2.Block diagram using DCT

Fig.2 shows the image compression using discrete cosine transform. In this method, input image is taken , it is converted into Gray Scale format. For this gray scale image Discrete Cosine Transform is applied. After applying the discrete cosine transform, the obtained matrix may be "D1".For this matrix "D1", the threshold "r" is applied. That means all those coefficients less than "r" are neglected. Then truncated D1 matrix is obtained. It is assumed that all those non zero coefficients present in the truncated matrix are transmitted. At the receiver, Inverse Discrete Cosine Transform is applied to "D1" matrix to reconstruct the image. Then reconstructed image is compared with different parameters. The computation time taken for Discrete Cosine Transform, Truncation of DCT and Inverse Discrete Cosine Transform is measured.

IV. IMPLEMENTATION

The experimentation is carried out on Matlab 7.6 using Intel(R) core i3 processor at 2.4 GHz. There are two methods namely (i) Image compression using DCT-SVD method and (ii) Image compression using DCT method.

The algorithm of the Image Compression using DCT-SVD method is as follows.

(i) Read an image.
(ii) If the image is any other format other than gray scale, convert it to gray scale image.
(iii) Then, this gray scale image is given as the input to the DCT. This gives discrete cosine transformed matrix.
(iv) Then for this discrete cosine transformed matrix, threshold of "r" is applied. That means all those coefficients less than "r" are neglected. Then truncated discrete cosine transformed matrix is obtained.
(v) This truncated discrete cosine transformed matrix is given as input to Singular Value Decomposition (SVD).This results in three matrices "U", "S" and "V".
(vi) Then in this "S" matrix, all those coefficients less than 200 are neglected. This gives the truncated "S" matrix.
(vii) Then matrix "U", truncated "S" matrix and transpose of "V" matrix are multiplied such that $D=U*S*V^T$.
(viii) Then, again the threshold of "r" is applied to the matrix "D". i.e all those coefficients less than "r" are neglected. It is assumed that non zero elements of this matrix "D" are transmitted.
(ix) Then Inverse Discrete Cosine Transform of this matrix "D" is taken to reconstruct the image.

(x) Then the parameters, Mean Squared Error (MSE), Peak Signal to Noise Ratio (PSNR) and Compression Ratio (CR) are evaluated.
The formulae are as follows.

$$MSE = \frac{\sum_{i=1}^{i=m}\sum_{j=1}^{j=n}[a(i,j)-b(i,j)]^2}{m\times n} \quad (3)$$

where m=number of rows of the image, n= number of columns of the image, a(i,j)= The element of the original image matrix at the i th row and j th column, b(i,j) is The element of the reconstructed image matrix at the i th row and j th column.

The Peak Signal to Noise Ratio is given by

$$PSNR = 10\log_{10}\frac{255^2}{MSE} \quad (4)$$

Where MSE=Mean Square Error

The compression ratio is given by

$$CR = \frac{m\times n}{r} \quad (5)$$

Where m= number of rows of the original image matrix, n=number of columns of the original image matrix. r=number of non zero elements in the transformed matrix to be transmitted.

(xi) Then computational time required to perform discrete cosine transform, truncation of DCT matrix, SVD, truncation of "S" matrix, multiplication of $D=U*S*V^T$, and inverse DCT is measured. For measurement, five trials of readings are taken and average of this is tabulated. This is done because it is running on windows operating system, Intel(R) core i3 processor, there exists issues with pipelining, scheduling, child process, cache memory access.

(xii) For different threshold values of "r" steps (iii) to (xi) are repeated.

The algorithm for the Image Compression using DCT method is as follows.

(i) Accept an image as the input.
(ii) Convert the input image into gray scale format.
(iii) Apply discrete cosine transform to the converted gray scale image.
(iv) Then discrete cosine transformed matrix of the input image is truncated by applying threshold "r". That is all those coefficients less than "r" in this matrix are neglected. The non- zero elements of the truncated matrix is assumed to be transmitted.
(v) In order to extract the image, Inverse Discrete Cosine Transform is applied.
(vi) For the reconstructed image, parameters such as Mean Squared Error, Peak Signal to Noise ratio and Compression Ratio are evaluated
(vii) Then the computational time required to perform DCT, to truncate DCT and to inverse DCT is measured. For measurement of computational time five trials are taken. Then average of this is tabulated.
(viii) For different thresholds steps (iii) to (vii) are repeated.

V. RESULTS AND DISCUSSIONS

. Experiments are conducted for different set of inputs by considering different resolution and different file formats such as .tiff, .png, .jpg etc. A sample of the experimental result is displayed for further discussion and analysis.

The details of the input image and its results are as follows.
Image name: river.jpg
Image size: 425x318

Original image

Figure 3. Input Image.

TABLE 1.RESULTS OF THE IMAGE COMPRESSION USING DCT SVD METHOD.

Sl. No.	r^{th}	U^{th}	S^{th}	V^{th}	MSE	PSNR (in dB)	CR
1	28	--	200	--	70.6260	29.6412	24.7936
2	30	--	200	--	74.2798	29.4221	27.0842
3	32	--	200	--	78.4751	29.1835	29.8015
4	34	--	200	--	82.7814	28.9515	32.7319
5	36	--	200	--	86.5760	28.7568	35.7162

Table.1 shows the results of the image compression using DCT-SVD method. The column "r^{th}" is the threshold for DCT matrix used for truncation and it is also the threshold for the truncated matrix $D=U*S*V^T$. The " U^{th} " is the threshold fixed for "U" matrix. The "--" represent no threshold is fixed for that matrix. The " S^{th} " is the threshold fixed for "S" matrix. The "V^{th}" is the threshold for "V" matrix.MSE is the Mean Squared Error, PSNR is the Peak Signal to Noise Ratio and CR is the Compression Ratio. There are five trials of experimentation. The corresponding MSE, PSNR and CR are tabulated. The corresponding reconstructed images are as follows.

TABLE 2. RECONSTRUCTED IMAGES

Trial1,PSNR=29.6412,CR=24.7936

Trial2, PSNR=29.4221,CR=27.0842

Trial3,PSNR=29.1835,CR=29.8015

Trial4,PSNR=28.9515,CR=32.7319

Trial5 PSNR= 28.7568 CR=35.7162

Table 2 shows the reconstructed images for the trials of experiment tabulated in Table1.

TABLE 3.RESULTS OF IMAGE COMPRESSION USING DCT

Sl.No.	r^{th}	MSE	PSNR (in dB)	CR
1	28	59.1607	30.4105	19.8225
2	30	63.2407	30.1208	21.9399
3	32	67.2789	29.8520	24.1728
4	34	71.4244	29.5923	26.6253
5	36	75.2739	29.3644	29.0583

Table 3 shows the results of the image compression using DCT method. "r^{th}" implies threshold fixed for DCT matrix for truncation. For five trials of the threshold the corresponding MSE, PSNR and CR are tabulated.

TABLE 4. COMPUTATION TIME FOR THE GIVEN THRESHOLD IN DCT-SVD METHOD

Sl.No.	r^{th}	U^{th}	S^{th}	V^{th}	Computational time (in m sec)
1	28	--	200	--	845.5
2	30	--	200	--	753.1
3	32	--	200	--	728.8
4	34	--	200	--	709.0
5	36	--	200	--	674.1

Table 4 shows the Computational for the given threshold in the DCT-SVD method. That is, if the r^{th} =28, after DCT of the input image, all those coefficients less than 28 are neglected. Similarly if the threshold value S^{th} = 200, all those coefficients less than 200 are neglected in the "S" matrix obtained after singular value decomposition. Then computation time required to perform DCT, truncation of DCT, SVD, truncation of "S" matrix, multiplication of $D=U*S*V^T$ and inverse DCT is measured. While conducting the experiment for each trial, computational time is measured five times and average of the five measured time is tabulated. The average is taken because computational time also depends on the constraints such as pipelining, cache memory access and scheduling.

TABLE.5 COMPUTATION TIME FOR THE GIVEN THRESHOLD IN DCT METHOD.

Sl.No.	r^{th}	Computational time (in m sec)
1	28	385.1
2	30	354.5
3	32	329.8
4	34	371.4
5	36	371.0

Table 5 shows the computational time for the given threshold in DCT method. In this "r^{th}" represent the threshold for the truncation of DCT matrix. The computation time is the time taken for performing discrete cosine transform, truncation of discrete cosine transform and inverse discrete cosine transform. While conducting the experiment for each trial, five times the computational time is measured and average of the five measured time is tabulated.

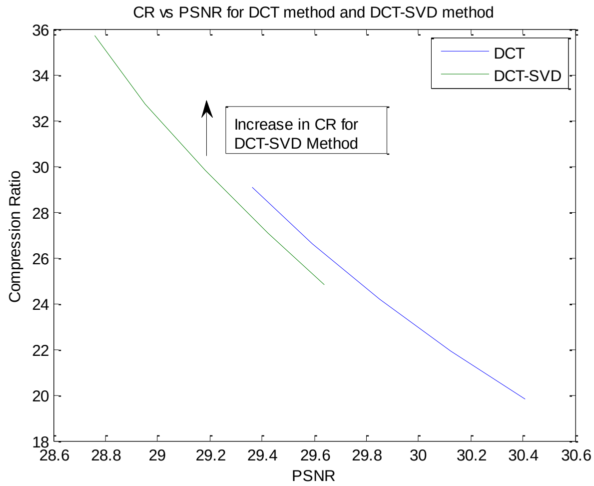

Figure 4. Plot of Compression Ratio vs. PSNR

Fig. 4 shows the graph of compression ratio versus PSNR for the set of thresholds as shown in Table 3. The detail analysis of threshold can be considered for the experimentation to relate with PSNR and CR .However the compression ratio varies significantly with respect to threshold which is discussed in the table 5 and 6.

It can be seen that for the given threshold the compression ratio obtained in the DCT-SVD method is more than the DCT method. At the same time, there is a decrease in the PSNR in DCT-SVD method. But this decrease in PSNR is minimal. The computational time for the DCT-SVD method is more compared to DCT method. That means this method finds an application where higher compression is needed with compromise of quality and computational time. But, it is observed that computational time decreases as we increase the threshold value.

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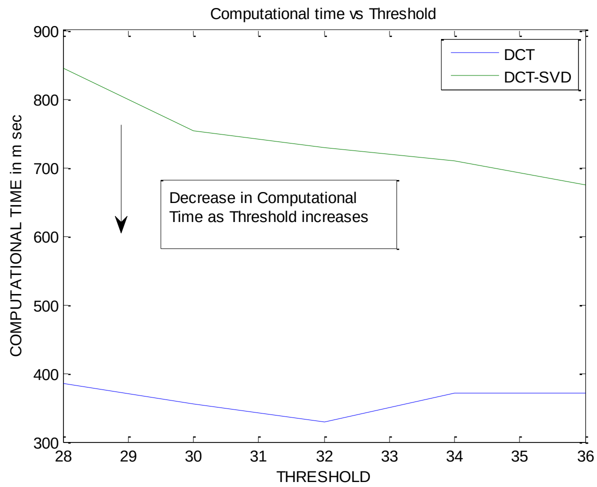

Figure 5. Graph of Computational time vs threshold.

Fig. 5 shows the graph of computational time versus the threshold for DCT method and DCT-SVD method. The graph shows in most of the cases as the threshold value increases, the computational time decreases. It can also be noted that as the threshold value range increases, there will be more reduction in the computational time.

TABLE 5. COMPARISON OF THREHOLD,COMPRESSION RATIO AND COMPUTATION TIME IN DCT-SVD METHOD FOR THE THRESHOLD OF 200 IN S-MATRIX OF SVD

Threshold "rth"	Compression Ratio	Computation time (in m sec)
28	24.7936	845.5
30	27.0842	753.1
32	29.8015	728.8
34	32.7319	709.0
36	35.7162	674.1

TABLE 6 .COMPARISON OF THREHOLD,COMPRESSION RATIO AND COMPUTATION TIME IN DCT METHOD

Threshold "rth"	Compression Ratio	Computation time (in m sec)
28	19.8225	385.1
30	21.9399	354.5
32	24.1728	329.8
34	26.6253	371.4
36	29.0583	371.0

Table 5 and Table 6 show the comparison of threshold, compression ratio and computation time in DCT-SVD method and DCT method respectively. The "r^{th}" implies threshold value applied for the DCT matrix. It is observed that for the given threshold of 28, the compression ratio obtained in DCT-SVD method is 24.7936 but in DCT method the compression ratio obtained is 19.8225. It shows that, there is a large increase in the compression ratio in DCT-SVD method, but at the same time the computation time also increases. The computation time in DCT-SVD method increases because of the SVD. The computation time involved in SVD can be reduced by applying fast computation of SVD.

VI. SCOPE FOR FURTHER ENHANCEMENT

In this method different threshold values are fixed to obtain the good compression ratio and to reduce the computation time to a smaller extent. However other possible transforms such as wavelet, KLT, Hadamard and slant can be explored. The proposed method can be extended by taking different combinations such as DCT-Wavelets, DCT-Hadamard and DCT-Slant.

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