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International Journal Of Modern Engineering Research (IJMER)

Image Compression using Hybrid Transform Coding

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***ABSTRACT**: Image compression is the one of the demand in the current trend to reduce the transmission bandwidth and the storage memory. In this paper we are proposing a hybrid compression technique for image using discrete cosine transform and singular value decomposition. It is proposed that using proper threshold value, the transformed results obtained using discrete cosine transform and singular value decomposition can be truncated. Using these truncated results of the transformation an effort is made to obtain the higher compression ratio with a reasonably acceptable quality.*
***Keywords:** DCT-Discrete Cosine Transform, SVD-Singular Value Decomposition, MSE-Mean Squared Error, PSNR-Peak Signal to Noise Ratio, CR-Compression Ratio.*

I. Introduction

There is an eternal demand for image compression in the field of multimedia. The challenging task is that as we compress the image the quality of the reconstructed image decreases. Image compression can be done using lossy compression techniques and lossless compression techniques. The transmission bandwidth consumed for the loss less compression is more than the lossy compression. Using lossy compression techniques, it is found that the acceptable quality of the reconstructed image can be obtained. Therefore it is advantageous to use lossy compression rather than lossless compression, provided reconstructed image quality is not the major concern. In this paper we are proposing a lossy compression scheme using Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD).

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

There are different contributions to the above discussed problem. Few papers are discussed in this section. Prasantha.H.S and others [1] have worked on image compression using SVD. Prasanta.H.S [2] and others have worked on H.264 decoders for performance evaluation. 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.

II. Methodology

The transformations used in the proposed experiment include discrete cosine transform (DCT) and Singular Value Decomposition (SVD) for image compression

2.1 Discrete Cosine Transform

The discrete cosine transform is a linear transform which maps an n-dimensional vector to set of “n” coefficients. A linear combination of n-known basis vectors weighted with the n-coefficients will result in the original vector. The formula for 2-dimensional DCT is as follows

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

The inverse 2-dimensional DCT is as follows

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

2.2 Singular Value Decomposition

Singular value decomposition is a matrix factorization technique. Given "A" matrix of the dimension m×n, the singular value decomposition of "A" is defined as $svd(A) = U * S * V^T$, where "U", "S" and "V" are the matrices of dimensions m×m, m×n and n×n respectively. The matrix "S" is a diagonal matrix having principal diagonal elements as non zero elements. The diagonal elements have the property $s1 \geq s2 \geq s3 \geq \cdots \geq sn$.The rank of the SVD decomposition is the number of non-zero elements in the in the S-Matrix. As the rank increases the computational complexity of the algorithm also increases.

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

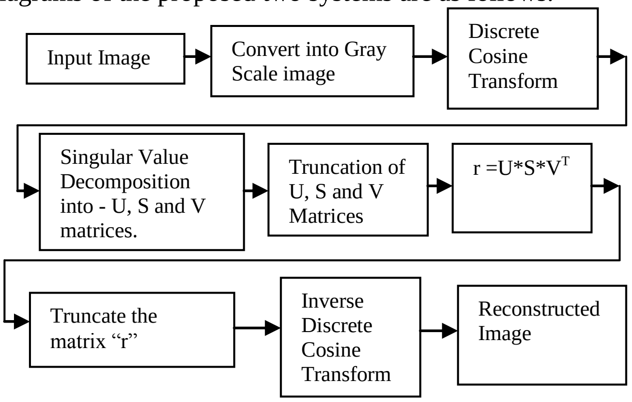


Fig1.Block diagram of image compression using DCT-SVD- DCT

Fig.1 shows the block diagram of the image compression using DCT-SVD-DCT. In this method, the image is taken at the input. If it is an RGB image, it is converted into gray scale image. Then discrete cosine transform of the gray scale image is taken. This discrete cosine transformed image is made to pass through the singular value decomposition. The singular value decomposition results in three matrices "U", "S" and "V". Then the thresholds for all these three matrices are fixed empirically. While conducting the experiment, the threshold for "U" matrix is fixed as 0.01, the threshold for "S" matrix is fixed as 1000 and the threshold for "V" matrix is fixed as 0.01.But the experiments are conducted for different thresholds for "U", "S","V" and "r" matrices. It is found that the above mentioned values are optimum. The coefficients less than these fixed thresholds in "U", "S" and "V" matrices are neglected. Then the truncated matrices "U", "S" and "V" are obtained. Now these truncated matrices are multiplied such that $r = U * S * V^T$. This "r" matrix again gives the truncated discrete cosine transform of the input image. In this "r" matrix again coefficients less than the threshold 40 are neglected. Then, in this "r" matrix, non-zero elements are assumed to be transmitted. At the receiver, the inverse discrete cosine transform of the matrix "r" is performed to reconstruct the image. This reconstructed matrix may be "r1".The reconstructed image "r1" is compared with different parameters.

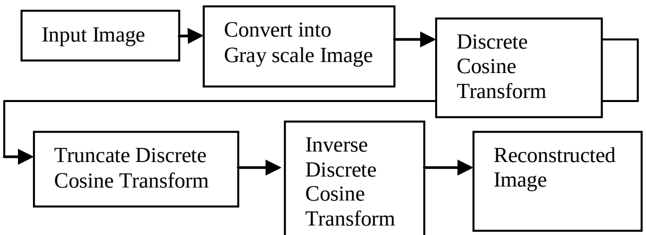


Fig2.Block diagram image compression using DCT

Fig.2 shows the image compression using discrete cosine transform. In this method, the discrete cosine transform of the image is taken. Let the discrete cosine transformed matrix be "r". In this matrix "r", coefficients less than the threshold "40" are neglected. Then in this matrix non-zero elements are assumed to be transmitted. Then inverse discrete cosine transform of the matrix "r" is taken to reconstruct the image. Let this matrix be "r1".Then again the reconstructed image matrix "r1" is compared with different parameters.

III. IMPLEMENTATIONS

The experimentation is carried out in MATLAB 7.6. For experimentation ten different images are considered. There are two methods; they are (1) image compression using DCT-SVD-DCT (2) image compression using DCT.

The algorithm of the implementation of the first method using DCT-SVD-DCT is as follows.

(i) Read an image.

(ii) If the image is in the RGB format, it is converted into gray scale format.

(iii) Then DCT is applied on the gray scale format of the image. Let the transformed matrix be “x”.

(iv) The SVD is applied to this matrix “x”, which gives three matrices “U”, “S” and “V”.

(v) Then in the first trial, the threshold for “U” matrix is fixed as 0.01.i.e all those coefficients less than 0.01 in the “U” matrix are neglected and the matrix “r” is formed as $r = U * S * V^T$.

(vi) Then the threshold for “r” matrix is fixed as 40.i.e all those coefficients less than 40 are neglected in this matrix. It is assumed that the non-zero elements in the “r” matrix are transmitted.

(vii) Then the inverse DCT of “r” matrix is taken to reconstruct the image.

(viii)Then the parameters Mean Squared Error (MSE), Peak Signal to Noise Ratio (PSNR) and Compression Ratio (CR) are evaluated.

The formulae are as follows.

$MSE = \frac{\sum_{i=1}^{i=m}\sum_{j=1}^{j=n}[a(i,j)-b(i,j)]^2}{m\times n}$ 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 ith row and jth column, $b(i,j)$=The element of the reconstructed image matrix at the ith row and jth column. --- (3)

The Peak Signal to Noise Ratio is given by

$PSNR = 10\log_{10}\frac{255^2}{MSE}$ Where MSE=Mean Squared Error. -- (4)

The compression ratio is given by

$CR = \frac{m\times n}{r}$ Where m= number of rows of the image matrix, n=number of columns of the image matrix. r=number of non zero elements in the transformed matrix to be transmitted. ---------------------------------- (5)

(ix) In the second trial, the threshold for “S” matrix is fixed as 1000. i.e all those coefficients less than 1000 in this matrix are neglected and the matrix “r” is formed as $r = U\ S\ V^T$ and steps (vi),(vii) and (viii) are repeated.

(x) In the third trial, the threshold for “V” matrix is fixed as 0.01. i.e all those coefficients less than 0.01 in this matrix are neglected and the matrix “r” is formed as $r = U\ S\ V^T$ and steps (vi),(vii) and (viii) are repeated.

(xi) In the fourth trial, the threshold for “U” matrix is fixed as 0.01, the threshold for “S” matrix is fixed as 1000 and the threshold for “V” matrix is fixed as 0.01.It implies that the coefficients less than 0.01 in the “U” matrix are neglected, the coefficients less than 1000 in the “S” matrix are neglected and the coefficients less than 0.01in the “V” matrix are neglected and the matrix “r” is formed as $r = U\ S\ V^T$ .Then steps (vi), (vii) and (viii) are repeated.

(xii) In the fifth trial no threshold is fixed for “U”, “S” and “V” matrix and the matrix “r” is formed as $r = U\ S\ V^T$ and then steps (vi), (vii) and (viii) are repeated.

(xiii)In the sixth trial no threshold is fixed for “U”, “S”, “V”, “r” matrix and the matrix “r” is formed as $r = U\ S\ V^T$ and then steps (vii) and (viii) are repeated.

The algorithm of the implementation of the second method using DCT is as follows.

(i)Read an image.

(ii) If the image is in the RGB format it is converted into gray scale format.

(iii) Then DCT is applied on the gray scale format of the image. Let the transformed matrix be “r”.

(iv) In the first trial, the threshold for the “r” matrix is fixed as 40.i.e all those coefficients less than 40 are neglected. It is assumed that non-zero elements are transmitted.

(v) Then the inverse DCT of “r” matrix is taken to reconstruct the image.

(vi) Then the parameters MSE, PSNR and CR are evaluated.

(vii) Then in the second trial no threshold is fixed for “r” matrix and step (v) and (vi) are repeated.

IV. RESULTS, DISCUSSIONS AND CONCLUSION

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: 318x425

Fig3. Input Image

Table1.Results image compression of input image using DCT-SVD-DCT

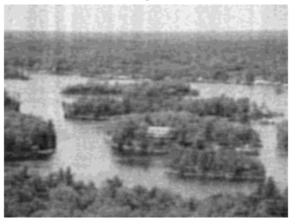
Trial	Uth	Sth	Vth	r th	MSE	PSNR (in dB)	CR
1	0.01	--	--	40	107.7358	27.8072	35.5939
2	--	1000	--	40	159.9778	26.0902	68.1887
3	--	--	0.01	40	100.3064	28.1175	35.6314
4	0.01	1000	0.01	40	201.1382	25.0959	75.5440
5	--	--	--	40	83.5369	28.9219	34.7162
6	--	--	--	--	7.8981×10^{-25}	289.1556	1

Table.1 shows the results obtained for the input image using DCT-SVD-DCT method. The “Uth”, “Sth”, “Vth”, “rth” represents the thresholds of “U”, “S”, “V” and “r” Matrices respectively fixed for truncation. The Column MSE represents the mean squared error between the original image and the reconstructed image. The Column PSNR indicates the peak signal to noise ratio. The column CR denotes the compression ratio between the original image matrix and the non-zero coefficients of the matrix to be transmitted. The symbol “--” represents no threshold is fixed for that matrix for truncation. There are six trials of experimentation for the given image. The corresponding reconstructed images and compression ratio are tabulated below.

Table 2. Reconstructed Images and their Compression ratio

<table>
<tr>
<td>

Trial 1, CR=35.5939</td>
<td>

Trial 2,CR=68.1887</td>
<td>

Trial 3,CR=35.6314</td>
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<td>

Trial 4, CR=75.5440</td>
<td>

Trial 5,CR=34.7162</td>
<td>

Trial 6,CR=1</td>
</tr>
</table>

Table 2. Shows the reconstructed images for the six trials. In each block the Reconstructed image, Trial number and Compression ratio are mentioned.

Table3.Results of image compression of the input image using DCT

Trial	r th	MSE	PSNR (in dB)	CR
1	40	83.3569	28.9214	34.7162
2	--	1.6296×10^{-27}	316.0099	1

Table.3 shows the results obtained for the input image using DCT method. The column "rth" represents the threshold fixed for the discrete cosine transformed matrix for truncation. The column MSE represents the mean squared error, the column PSNR represents the Peak Signal to noise ratio and the Column CR represents the Compression ratio. The symbol "--" represents no threshold is fixed for that matrix for truncation. There are two trials of experimentation for the given image. The corresponding reconstructed images and compression ratio are tabulated below.

Table 4. Reconstructed Images and their Compression ratio

 Trial 1, CR= 34.7162	 Trial 2, CR=1

Table 4. Shows the reconstructed images for the two trials. In each block the Reconstructed image, Trial number and Compression ratio are mentioned.

From the experimentation results obtained for different images, bar charts of compression ratio against the trials and PSNR against the trials are plotted for both DCT-SVD-DCT method and DCT-method. They are as follows

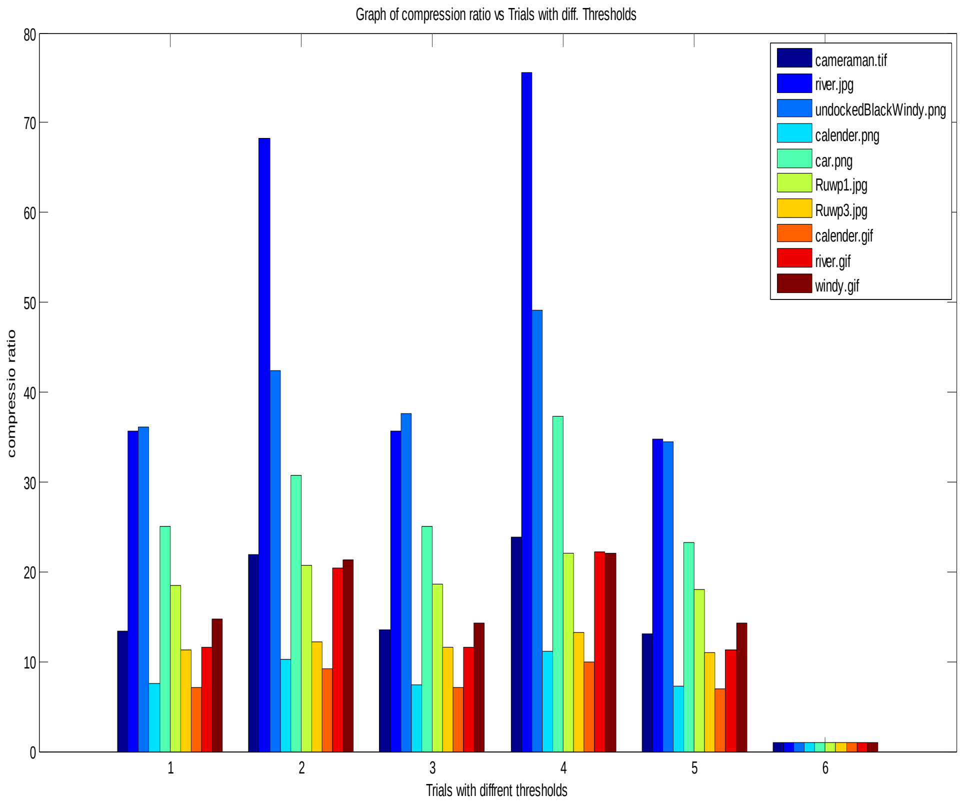

Fig.4. Plot of Compression ratio vs Trials with different thresholds for DCT-SVD-DCT method

Fig.4 shows the plot of compression ratio vs. trials for different images plotted for DCT-SVD-DCT method. In this x-axis represents the trials and the y-axis represents the compression ratio. There are six trials. In first trial, threshold for "U" matrix is 0.01, and threshold for "r" matrix is 40. That means with respect to threshold, all those coefficients less than 0.01in the "U" matrix are neglected and all those coefficients less than 40 are neglected in the "r" matrix .This threshold is maintained same for all the ten different images and the corresponding compression ratio are plotted in the y-axis. In the second trial, threshold for "S" matrix is 1000 , the threshold for "r" matrix is 40. i.e. all those coefficients less than 1000 in the S matrix are neglected and all those coefficients less than 40 are neglected in the "r" matrix , this threshold is maintained same for all the ten different images and the corresponding compression ratio are plotted. In the third trial, the threshold for "V" matrix is 0.01 and the threshold for "r" matrix is 40. i.e. all those coefficients less than 0.01 in the "V" matrix are neglected and all those coefficients less than 40 are neglected in the "r" matrix, this threshold is maintained same for all the ten different images and the corresponding compression ratio are plotted. In the Fourth trial, threshold for "U" matrix is 0.01, the threshold for matrix "S" is 1000 , the threshold for "V" matrix is 0.01 and the threshold for "r" matrix is 40. i.e. all those coefficients less than 0.01 in the "U" matrix are neglected, all those coefficients less than 1000 in the "S" matrix are neglected, all those coefficients less than 0.01in the "V" matrix are neglected, all those coefficients less than 40 in the "r" matrix are neglected, this threshold is maintained same for all the ten different images and the corresponding compression ratio are plotted. In the fifth trial the threshold for "r" matrix is 40, i.e. all those coefficients less than 40 are neglected in the "r" matrix, this threshold is maintained same for all the ten different images and the corresponding compression ratio are plotted. In the sixth trial there is no threshold for all the matrices. For this trial also compression ratio is plotted for all ten different images. In this trial compression ratio of one is obtained. It is observed that in the fourth trial for the image river.jpg maximum compression ratio of 75.5440 is observed.

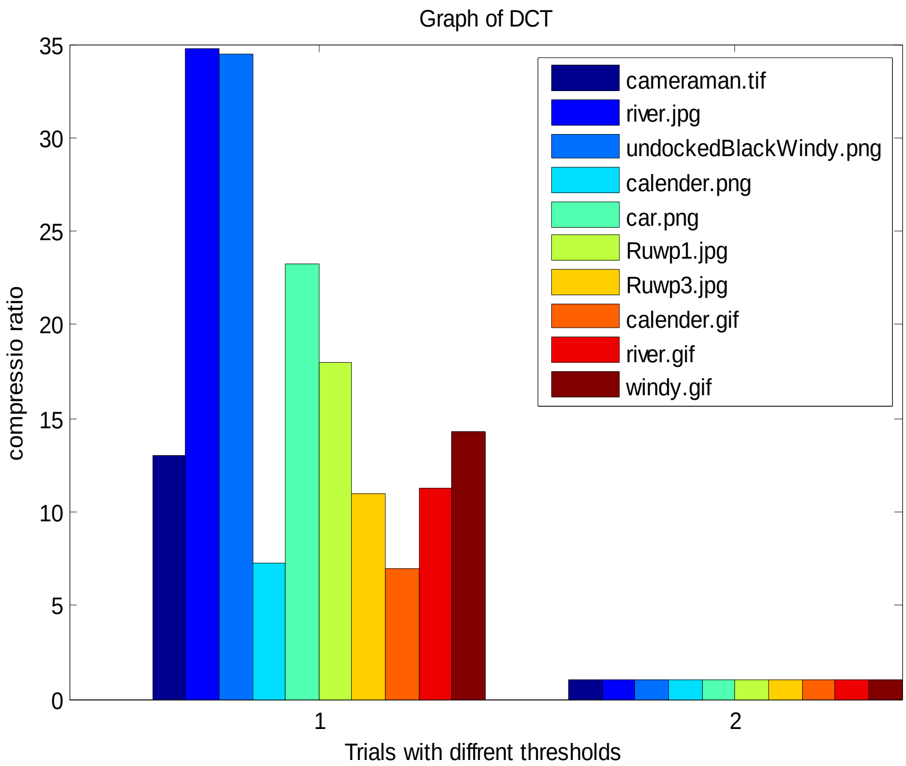

Fig.5. Plot of Compression ratio vs Trials with different thresholds for DCT method.

Fig.5 shows the plot of compression ratio vs. trials for image compression using DCT. There are two trials. In the first trial, threshold for r matrix is 40. It implies all those coefficients less than 40 are neglected in the "r" matrix, this threshold is maintained same for all the ten different images and the corresponding compression ratio are plotted. In the second trial no threshold is fixed for the "r" matrix. For this trial also compression ratio is plotted for all ten different images. In this trial compression ratio of one is obtained. It is observed that maximum compression ratio of 34.7162 is obtained for river.jpg image in the first trial.

Therefore it can be concluded that in DCT-SVD-DCT method higher compression rate can be obtained. But the disadvantage of this method is that, increase in the computation time. It also makes the algorithm complex.

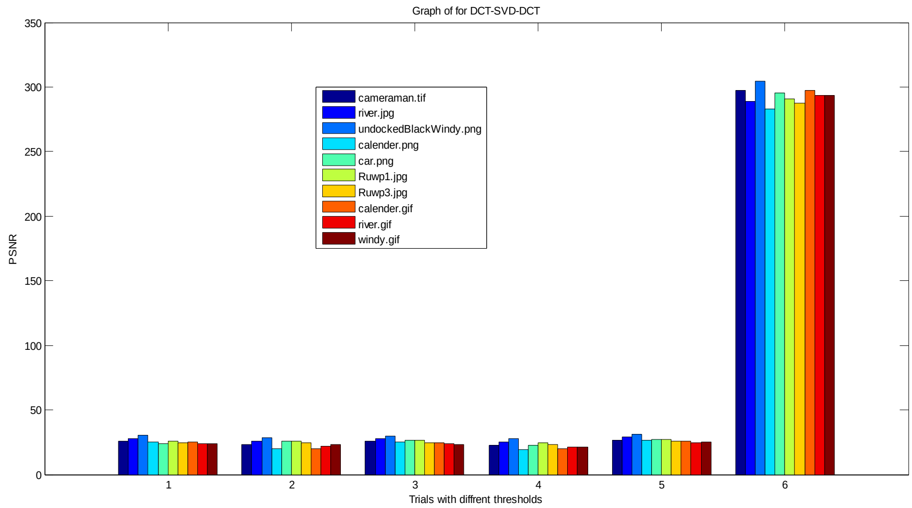

Fig.6. Plot of PSNR vs Trials with different thresholds for DCT-SVD-DCT method

Fig.6 shows the graph of PSNR vs. Trials for DCT-SVD-DCT method. There six trials for ten images. In each trial thresholds for “U”, “S”, “V” and “r” matrices are varied for all the ten images as explained for Fig.4. But in this case corresponding PSNR of all ten images are plotted in each trial. It is observed that in the fourth trial for the image river.jpg 25.0959 dB is obtained. Even though PSNR is less, it possible to reconstruct the image ,with reasonably acceptable quality.

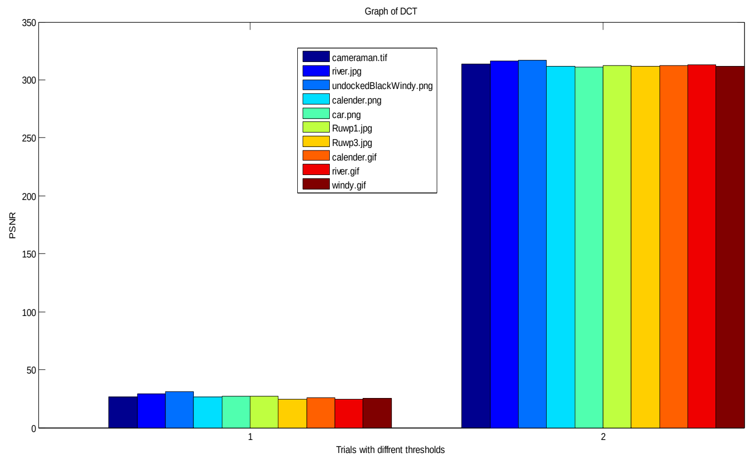

Fig.7. Plot of PSNR vs Trials with different thresholds for DCT method.

Fig.7 shows the graph of PSNR vs. Trials for DCT method. There are two trials for images. In each trial threshold for “r” matrix is varied for all the ten images as explained for Fig.5. In this case also corresponding PSNR of all ten images are plotted in each trial. It is observed that in the first trial for the image river.jpg the PSNR obtained is 28.9214.

It is observed that as the compression ratio increases the corresponding PSNR decreases in both the methods. i.e. using DCT-SVD-DCT method and DCT method. However, the image can be reconstructed with an acceptable quality.

Another important observation made is that, in the image compression using DCT-SVD-DCT method, the compression ratio obtained is more than the compression ratio obtained using DCT method for the same threshold. However, DCT-SVD-DCT method increases computational complexity compared to DCT method.

V. Scope For Further Enhancement Conclusion

In this method different threshold can be fixed to obtain good compression ratio. However experimentation can be done to achieve higher compression ratio with an acceptable quality with other transforms such as wavelet, KLT, Hadamard , slant etc. The work can also be extended by choosing Hybrid combinations such as DCT and Wavelets, DCT and Hadmard , DCT and Slant.

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