COMPARISON AND PERFORMANCE EVALUATION OF ADVANCED SVD AND DCT FOR COLOR IMAGE COMPRESSION

Garima Garg
Department of Computer Science and Engineering
I K Gujral Punjab Technical University,
Kapurthala, Punjab, India
garimagarghce@gmail.com

Raman Kumar
Department of Computer Science and Engineering
I K Gujral Punjab Technical University,
Kapurthala, Punjab, India
er.ramankumar@aol.in

Abstract- Image compression research has increased significantly because of increasing demands for image transmission in computer and mobile environments. When calculating the amount of bits per image from conventional quantization methods and sampling rates, image compression is required. As a result, it has become necessary to develop efficient image compression techniques. Color images are in trend these days during communication. Most of the researchers have worked only on grayscale image compression. Colored image channels have been handled exclusively for many years, or color image is transformed into grayscale image. Improvements have been made to image compression algorithms SVD and DCT. In this paper, seven standard images have been used for compression using DCT and SVD, individually for experimental purposes. The performance of the model is measure on the basis of various performance matrices like Peak Signal to Noise Ratio, Mean Square Error, Normalized Co-relation (NC), Volumetric Efficiency, and percent space savings.

Keywords: Discrete Cosine Transform (DCT); Image Compression; Discrete Wavelet Transform (DWT); Singular Value Decomposition (SVD);

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I. INTRODUCTION

Compression of digital images minimises the quantity of data necessary to display them. More pictures can be stored in the same measure of memory space if a size is reduced. Additionally, it minimises the time it takes to deliver photographs over the Internet [Sindhu & Rajkamal (2009)]. The field of image compression is vast and well-researched. There are various methods for compressing image files. TIFF, JPEG, and wavelet are examples of file formats. Because TIFF images contain a lot of information, they are huge. This is the most widely used file format for photo processing. Compressed image formats such as JPEG and GIF are most commonly utilised for internet applications. JPEGs can be used for pictures, while GIFs are used for simple lines and other geometric images in order to replace GIF, PNG was invented. Print photography practically seldom makes use of it [Arora & Shukla (2014)].

Lossy compression lowers data loss whereas lossless compression keeps the original image intact. Compression algorithms such as Discrete Fourier Transform (DFT), Discrete Walsh-Hadamard Transform (DWHT), and Wavelet Transform play an important role in the data compression procedure. Every one of these alterations can be undone in the same way. The primary objective is to create picture compression systems with an optimal signal-to-noise ratio and compression rates [Cooper & Lolenc (2006); Kang & Wei (2008)]. As data-intensive media web services gain popularity, better signal and image encoding is necessary that elevating signal reduction to a necessary element of storage and communications technologies [Aishwarya et al., (2016)].

II. LITERATURE REVIEW

[Ahumada & Peterson (1992)] created a model of DCT coefficient quantization which would be based here on the peak-to-peak brightness of an error picture. A simple light levels detection method may forecast R, G, or B DCT visible thresholds tested experimentally. DCT coefficient encoding matrices at display settings besides the ones used in the research (pixel intensity spacings, viewing distances, or aspect ratios). [Shen & Delp (1997)] suggested a curvelet coding scheme for colour images leveraging a luminance/chrominance colour system. An embedded coding method, analogous to Shapiro's embedded zero tree wavelet (EZW) method, was applied to provide bit rate scalability. The three color elements in a luminance/chrominance hue saturation value (hsv) color space show minimal statistical connection. However, significant shifts in the luminance output have indeed been recorded at spatial areas were luminance signals exhibit transformation. The recommended strategy takes use of dependency between the colour components.

[Yang & Tsai (1998)] used quantization, median filter, and background subtraction in conjunction with the instant principle to offer a new way to colour picture compression. The result was high compression ratios and good quality fused images. Adaptive still colour picture compression provides automatically chosen region of interests (ROIs) with greater performance gain than the remainder of the source images. The multicue gaze algorithm selects the aspects of a picture that are most aesthetically attractive. As a result, while working using low bandwidth systems, adaptive coding prefers image sections which are more visible to the human visual. This adaptive technique provides compressed multiple images that are perfectly compliant with the original image, enabling for widespread adoption.

According to [Chang & Ding (2003)], a quaternion matrix's SVD could be determined using its complicated construction equivalent. As a result, colour images are processed using SVD's powerful image processing techniques such as eigen-images, compression, augmentation, and denoising. Starting with an overview on spatial frequency contrast enhancement and how it can be measured for brightness and colour. As a consequence, [Nadenau et al., (2003)] resolve the issue of noise shape in the setting of sensory acuity. The Contrast Sensitivity Function (CSF) was approximated using a DWT-based encoder, and several implementation alternatives were studied to find the best possible compression quality. The modified hybrid model suggested by [Wongsawat et al., (2004)] can encode both monochrome and colour images.

[Thakur & Kakde (2007)] developed the color image compression with the modified fractal coding technique for the compression of colour images. In order to compress the images, trichromatic coefficients were used to create one-plane images. Modified Fractal Grey Levels Image Coding Method was used to encode this Spiral Architecture image.

Three existing digital picture compression options were tested by [De et al., (2008)] including JPEG XR decompression, JPEG 2000 and JPEG. Perceptional quality criteria that take into consideration colour information are included in the study's Full Reference measurements. The symbolic Generalized Hebbian Algorithm and quaternion neural networks were used by [Luo et al., (2010)] to construct a new colour image principal components tool. The quaternion field was used to evaluate the neural show's powerful approaching ability, and the findings were encouraging. Wavelet packet optimal tree and Threshold entropy were used by [Kharate & Patil (2010)] to develop a new image compression method. [Douak et al., (2011)] studied the creation of a lossy colour still image compression method. YCbCr to RGB conversion, iterative phase (using bisection approach), quantization, dequantization, inverse DCT, and mean recovery were all used to complete the DCT transformation.

In the quantization process, [Maharani et al., (2013)] developed a graph-coloring method for image compaction schemes based on Wavelet-SVD. Images having a high current average variation or photos with a low resemblance between their sub-blocks are outperformed by the developed technique, which gives a reduced error rate during in the de quantization procedure, results in higher peak PSNR value. To reduce the size of a colour image, [Bhagat et al., (2014)] applied the DCT method and found that the PSNR and MSE could be improved. [Barbhuiya et al., (2014)] investigated and compared DWT and DCT-based picture compression techniques. DCT and DWT were compared using JPEG and PNG colour images to show the outcomes of this compression technology. [Kekre et al., (2016)] combined vector quantization with a hybrid wavelet transform (HWT). Using Discrete Kekre Transform (DKT)-DCT Harmonic Wavelet Transform (HWT), an average compression ratio of 32 resulted in acceptable image quality. Vector Quantization (VQ) was utilised on transform domain images because HWT had a strong blocking impact at a compression ratio of 64.

SVD-based colour image reduction was developed by [Li et al., (2017)]. Color images were used to construct a new real rectangle matrix C and then applied real SVD to it. The colour image was then compressed using the left and right unitary matrices by picking multiple highest singular values and their related vectors. Lossless colour image compression has been enhanced by [Zhou et al., (2018)] with a new encoder. As a result, the coefficients of the DCT were divided into two groups: DC and AC, each encoded using a unique encoder. The compression efficiency of each section is further enhanced using Huffman coding. Starting with their definitions, [Kahu et al., (2019)] offered an overview of 38 key colour spaces, beginning with their mathematical formulation, advantages, limitations, applications, and compression suitability. As early as the 1950s, colour spaces were classified according to how many components were required to form each one, as well as their perceived linearity and homogeneity.

An efficient colour picture compression approach was discovered by [Messaoudi et al., (2019)] non zero (NZ) and I DX vectors were used in a varied scanning sequence in the suggested approach. NZ-DCT coefficients and the duration of the zero-run sequence before a nonzero DCT coefficient are included in these vectors. Pressure changes and the double random encryption were used to develop a new colour picture compression and the encryption technology. It saves bandwidth and storage space by compressing the cypher image [Chai et al., (2020)]. Color images' sparse coefficient matrices were randomly shuffled using this method.

III. PROPOSED METHODOLOGY

In this section the in-depth detail of the research methodology is presented. The proposed methodology comprises of two different techniques one is the SVD and other is the DCT. Both the state-of-the-art techniques have been implemented with advancement for the color images.

A. Applications of SVD for Image Compression

To keep an image's entries to a minimum, an image matrix approximation of size mxn is required. The rank of a matrix can be used to eliminate any unnecessary data (dependent entries). There is no change in image when dependent terms with 0 singular values are included because the values are always higher than zero. Even more accurate matrices can be generated by eliminating extraneous singular components from the matrix A. The last terms on the list have the least effect on the overall picture because they are listed in ascending or descending order.

In the suggested strategy, segment the image into smaller blocks of sub images of size 64 X 64 rather than immediately applying an advanced SVD to the image. SVD computation process is then applied to each of these sub-images separately. Individual sets of the U, S, and V matrices are utilised to recompute corresponding 64 X 64 blocks in order to rebuild the image. To create the full image, these blocks are then rearranged and located in the original locations.

There is a lot of research on SVD's application to picture compression [Shruthi et al., (2016)]. SVD is used in order to find the approximation if the picture, when viewed as the matrix, having low rank or sufficiently well represented by the matrix of having low rank. Furthermore, the approximation of low rank is recorded considerably more compactly than real image. Let's say, for the sake of simplicity, that we are given an image A, which consider to be a N X N original matrix. Then, first factor it into SVD form $A = U \sum V^T$, where the $\sum$ is the diagonal matrix with an entries along the diagonal ordered in the non-increasing order, and U, V are orthogonal matrices. Then the rank "r" approximation to "A" is the matrix $A_r = U_r \sum r V_r^T$, where $\sum r$ is the top-left r x r sub matrix of Σ, Ur consists of the first r columns of U, and V_r^T the first r rows of V^T. Because U_r, Σ_r, V_r offer the best rank "r" approximation to "A" in terms of packing the most energy from "A", the SVD decomposition is intriguing. Additionally, the decomposition for compression is intriguing since, unlike "A", which has "N^{2}" entries, U_r, Σ_r, V_r^T only has 2Nr + r entries. The method is attractive because it frequently turns out that even with low r, the approximation Ar captures the majority of the energy of A and is aesthetically acceptable.

In the suggested method, we first increase the given image's size to the following integral multiples of 64 by reproducing the final row and/or column the necessary number of times. It is then broken into 64 x 64 blocks, with SVD being applied to each block separately. The rank r of SVD is calculated. As a result, we are left with 2 x 64 x r + r = 129r pixel values instead of the original block's 4096 pixel values. Thus for an image of dimension "M x N" where "M" and "N" are an integral multiples of 16 need to store $\frac{M\,x\,N}{64\,x\,64}$ x 129r = m x n x 129 r pixel values compared to M x N pixel values, where m = M/64 and n = N/64. The values of U, S, and V for each block are utilised to reconstruct the block during the reconstruction phase, and these m x n blocks are then organised in the same way they were segmented from the original picture matrix. As a result, the complete image is rebuilt. The recreated version of the original picture resembles an SVD approximation with rank R equal to r x $\frac{(\frac{m}{bl} * \frac{n}{bl} * (2*bl+1))}{(M + N + 1)}$ applied to the entire image at once. The schematic block diagram of the advance SVD approach is shown in the figure 1.

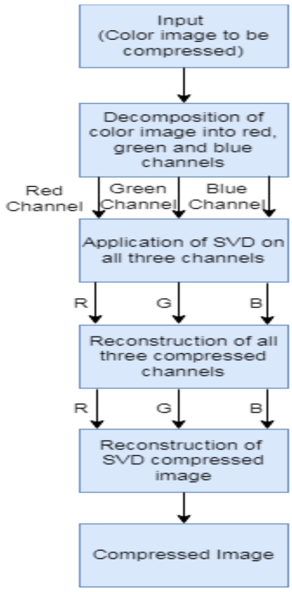


Fig. 1. Color image compression using advanced SVD

Following are the summarized form of the advanced SVD image compression technique:

- Inputting of the color image to be compressed.
- Decomposition of a color image into red, green and the blue channels.
- Applications of SVD method on all three channels to decompose them into three matrices U, S, V, such that given in the Eq. 1.

$$A = USV^T \qquad (1)$$

- Reconstruction of all three compressed channels.
- Reconstruction of SVD compressed image by combining all three compressed channels.

The implementation of the above steps may be understood through the block diagram as shown in Fig. 1.

B. Application of DCT for Image Compression

DCT is mostly used to divide images into portions with different frequencies. Wherein the image is only recovered using the most crucial frequencies throughout the decompression process, and the less crucial frequencies are ignored. Using a DCT, the image is divided into low- and high-frequency coefficients, or fundamental frequency components. Mathematically, The DCT decomposition can be understood from Eq. (2) and Eq. (3).

$$y(k) = w(k) = \sum_{n=1}^{N} x(n) \cos\left(\frac{\pi}{2N}\right)(2\text{n} - 1)\,(\text{k} - 1), \text{k} = 1,2,\ldots.,\text{N}, \qquad (2)$$

$$\text{Where}, \text{x}(n) = \begin{cases} \frac{1}{\sqrt{n}}, & n = 1, \\ \sqrt{\frac{2}{n}}, & 2 \leq n \leq N, \end{cases} \qquad (3)$$

Where "N" is a length of "x", and "x" and "y" are of same sizes. If "x" is the matrix, DCT changes the columns. Instead of the normal n = 0 and k = 0, the series is indexed from n = 1 and k = 1.

Following are the summarized form of the advanced SVD image compression technique:

- Inputting the color image to be compressed.
- Decomposition of a color image into red, green & blue channels.
- Application of DCT method on all three channels to find discrete cosine transform coefficient of all three channels.
- Calculations of the energy of each coefficient by squaring them.
- Sorting amongst all the coefficients from higher to lower value.
- Declaration of a suitable threshold value as per the pixel size of the input image.
- Extract higher energy coefficients from all three channels according to threshold values and replace all low-valued coefficients with zeros.
- Reconstruction of all three channels with high-value coefficients by applying inverse DCT.
- Reconstruction of DCT compressed image by combining all three compressed channels.

The basic schematic block diagram of the advanced DCT is shown in the fig. 2.

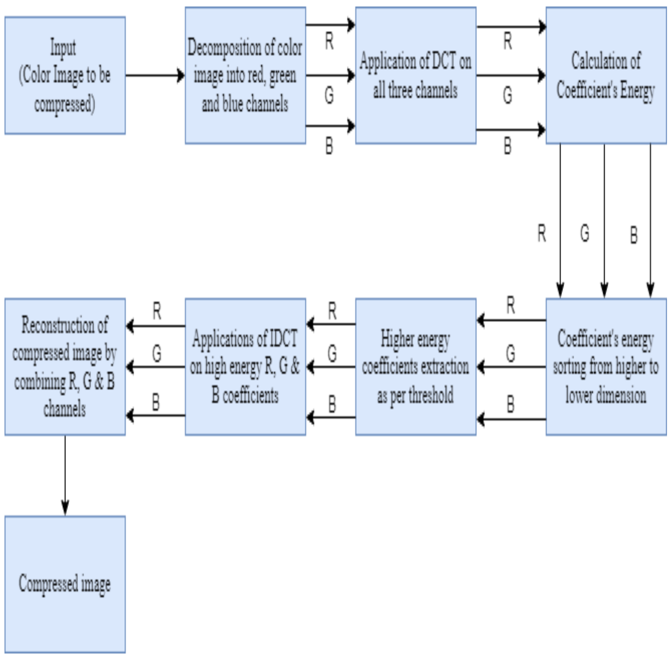


Fig. 2. Color image compression using advanced DCT

IV. EXPERIMENTAL RESULTS

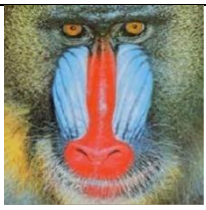
This research proposes an advanced version of two state-of-the-art and efficient image compression techniques DCT and SVD. SVD breaks down the given digital picture matrix into three vectors. At the concluding final step, singular values are employed to rebuild the image. Now, every image is represented using a reduced range of ethics that reduce the picture's storage capacity. At the same time, DCT decomposes an image into low and high-frequency coefficients. DCT is followed by quantization. Quantization is used to reduce most of the insignificant DCT coefficients with high-frequency to zero.

Here in this research, seven standard images have been used for compression using DCT and SVD, individually for experimental purposes. MATLAB R2022 has been used to implement the proposed methodology using generalized MATLAB Toolbox and Image

Processing Toolbox. For experimental purposes, a set of seven standard images has been taken. These images are 'Baboon.bmp,' 'Barbara.bmp,' 'House.bmp,' 'Lena.bmp,' 'Peppers.bmp,' 'Garima.bmp' and 'Airplane.bmp'. The pixel size of each image is 256 x256, except 'Garima.bmp'. The size of 'Garima.bmp' is 1029x1280. To calculate the performance of both the methods, the performance evaluation matrices, i.e., size after Compression, MSE, PSNR, Normalized Co-relation, Compression Ratio, and % space-saving, have been taken into account. At the end the comparison of the results based on both of the state-of-the-art techniques is shown.

Firstly, the advanced SVD method has been incorporated for compressing RGB images. All the above images and performance evaluation metrics have been used for this purpose. The value of these performance evaluation metrics has been given in Table 1.

Table 1. Performance analysis of SVD method on different images

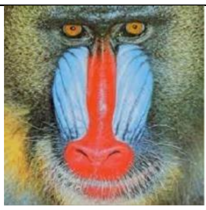
S.No.	**Image to be compressed**	**Original Memory Size (pixel size)**	**Size after Compression**	**MSE**	**PSNR**	**Normalized Co-relation**	**Compression Ratio**	**% Space Saving**
1	 Baboon.BMP	193KB (256x256)	16KB	34.6974	32.7278	0.9704	12.06	91.7
2	 Barbara.BMP	193KB (256x256)	13KB	14.3085	36.5749	0.9930	14.84	93.26
3	 House.BMP	193KB (256x256)	11KB	7.1203	39.6058	0.9966	17.54	94.2

4	 Lena.BMP	193KB (256x256)	12KB	8.3227	40.3452	0.9812	16.08	93.7
5	 Peppers.BMP	193KB (256x256)	12KB	6.6017	39.9343	0.9874	16.08	94.2
6	 Garima.BMP	3861KB (1029x1280)	153KB	31.5288	33.1437	0.9893	25.23	96.03
7	 Airplane.BMP	149KB (225x225)	13KB	19.5268	35.2245	0.9926	11.46	91.2

Analysis from Table 1 says that SVD is also working efficiently for all seven images. The value of the compression ratio is lying between 11 to 26. The said method is also able to compress the images with a range between 91 – 96.03%.
Secondly, as discussed in the proposed methodology section, the advanced DCT compression method is applied on all seven color images. Performance evaluation matrices have been calculated and given below in Table .

Table 2. Performance analysis of DCT method on different images

S.No.	**Image to be compressed**	**Original Memory Size (pixel size)**	**Size after Compression**	**MSE**	**PSNR**	**Normalized Co-relation**	**Compression Ratio**	**% Space Saving**

1	 Baboon.BMP	193KB (256x256)	17KB	32.9448	32.9444	0.9719	13.67	92.3
2	 Barbara.BMP	193KB (256x256)	13KB	13.0567	36.9296	0.9934	15.76	94.6
3	 House.BMP	193KB (256x256)	11KB	6.0891	40.2475	0.9971	18.68	95.8
4	 Lena.BMP	193KB (256x256)	12KB	6.1904	40.2136	0.9970	17.38	94.5
5	 Peppers.BMP	193KB (256x256)	11KB	6.5766	39.9508	0.9971	16.34	95.7
6	 Garima.BMP	3861KB (1029x1280)	183KB	30.5168	31.8299	0.9838	26.09	97.26
7	 Airplane.BMP	149KB (225x225)	13KB	18.8626	33.5274	0.9868	12.26	92.4

Analysis from Table 2 says that DCT is working efficiently for all seven images. The value of the compression ratio is lying between 12 to 26. The said method is also able to compress the images with a range between 92 - 97.2%.

To under the above comparison table, a detailed graphical analysis is also prepared and given below. Three special performance evaluation matrices, i.e., MSE, Compression Ratio, % space-saving, have been calculated and compared..

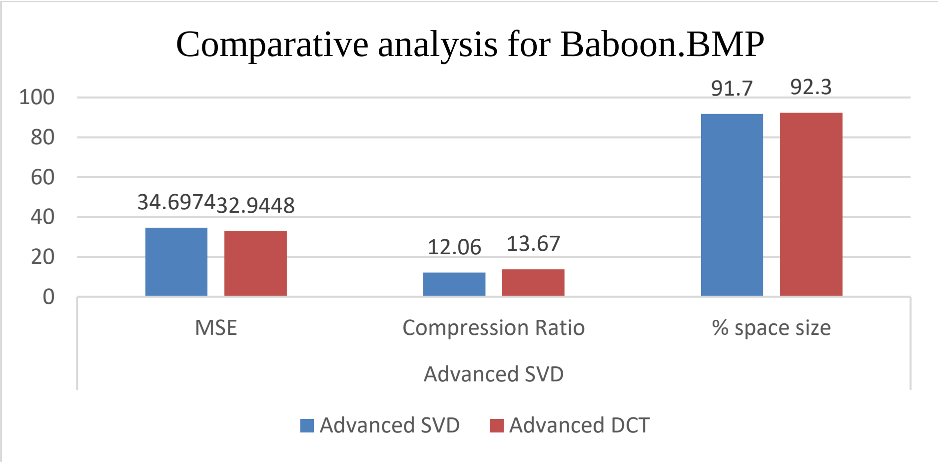


Fig. 3. Different performance assessment parameter for comparative analysis for Baboon.bmp

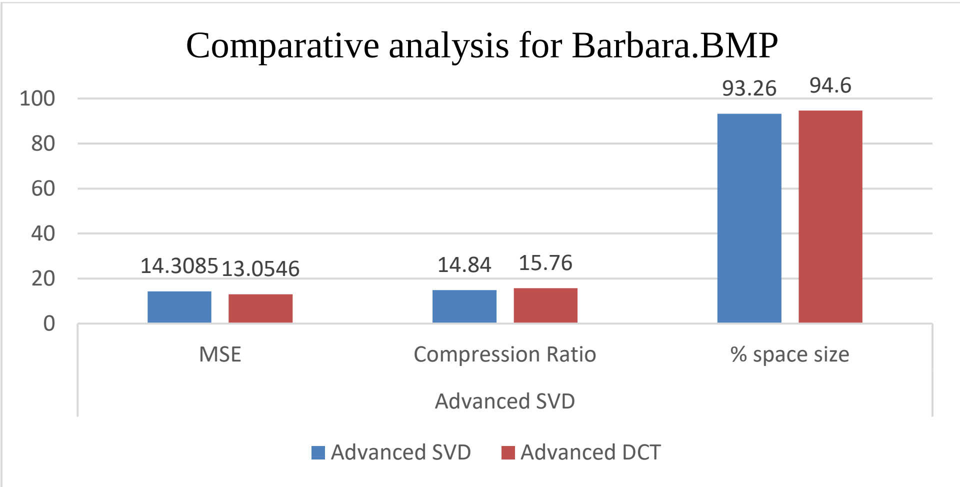


Fig. 4. Different performance assessment parameter for comparative analysis for Barbara.bmp

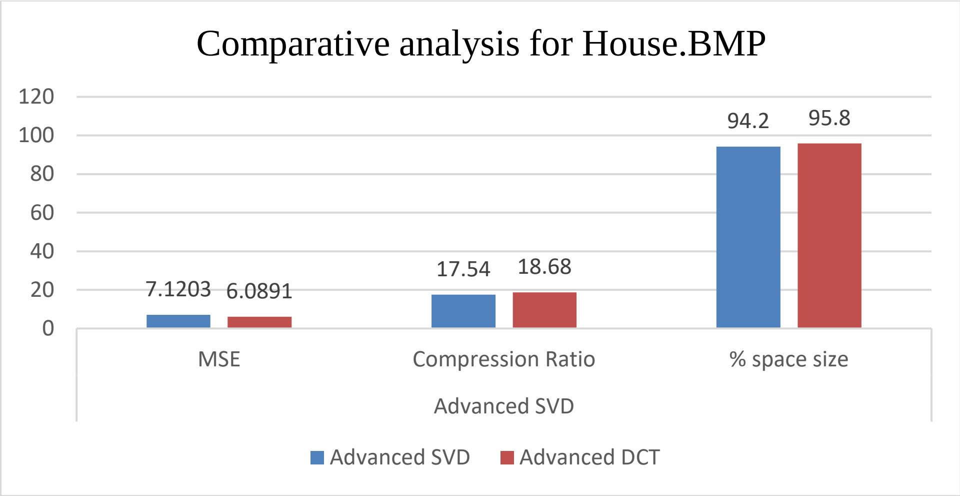


Fig. 5. Different performance assessment parameter for comparative analysis for House.bmp

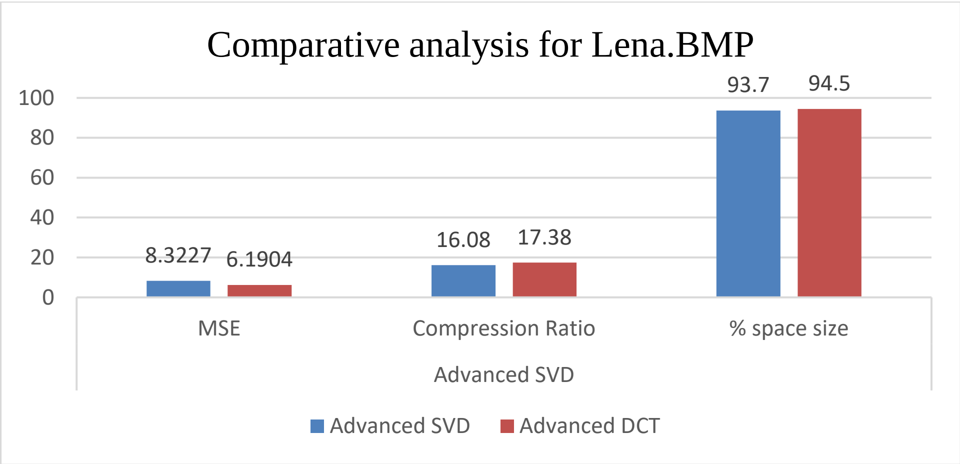


Fig. 6. Different performance assessment parameter for comparative analysis for Lena.bmp

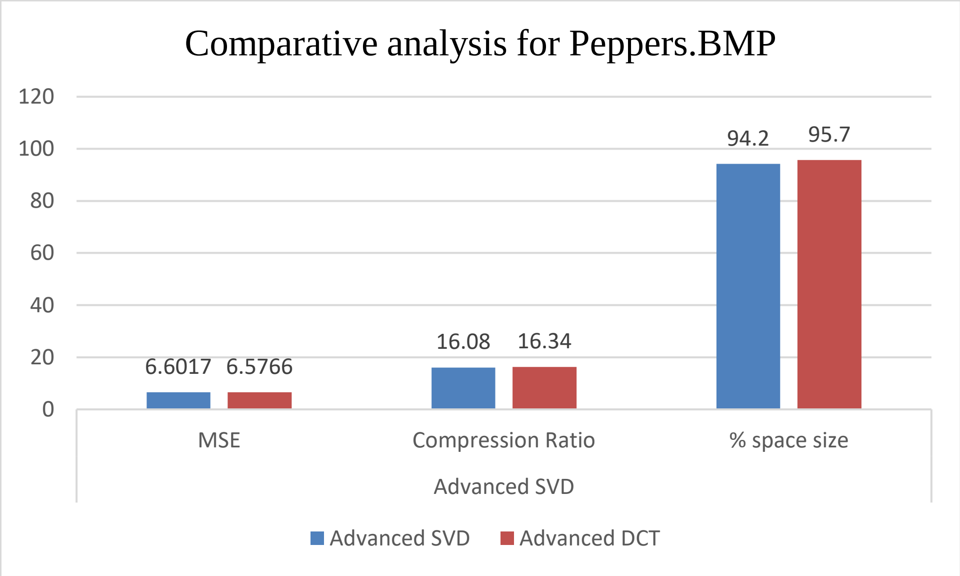


Fig. 7. Different performance assessment parameter for comparative analysis for Peppers.bmp

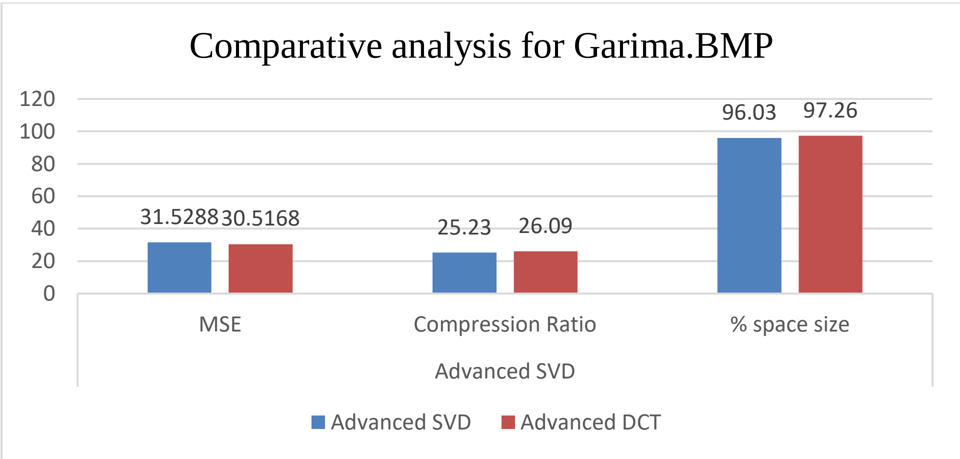


Fig. 8. Different performance assessment parameter for comparative analysis for Mohit.bmp

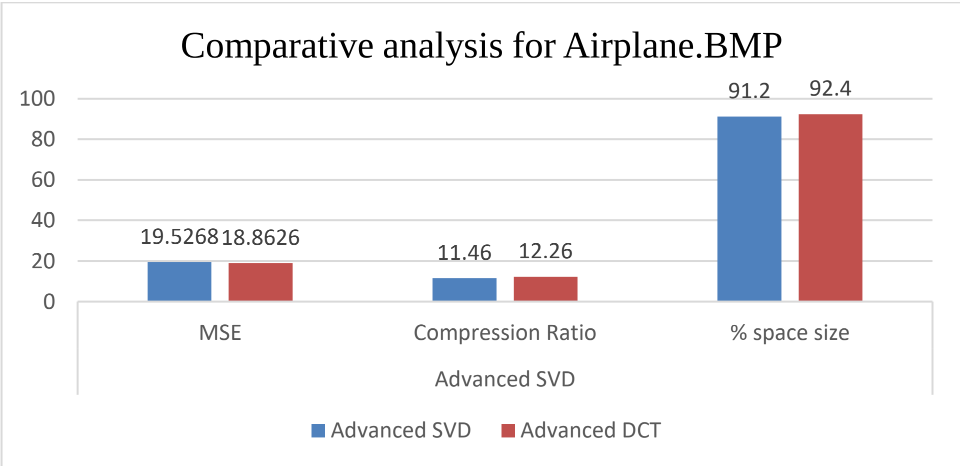
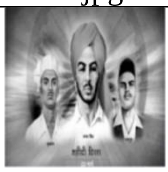


Fig. 9. Different performance assessment parameters for comparative analysis for Airplane.bmp

It can be noticed that the advanced DCT method works efficiently to compress the color images in comparison to the SVD.

The proposed method is also compared with the existing DCT method [29] using three parameters, i.e., CR. MSE and PSNR. Ankit Chouhan et al. [29] considered three images, i.e., 'horse.jpg,' 'bhagat.jpg,' and 'boy.jpg', for the experimental purpose. The comparative analysis of all three parameters for all three images has been given in the table below.

Table 3 Comparative analysis of all three parameters for all three images for the existing and proposed method

S. No.	Image to be compressed	Compression Ratio		MSE		PSNR	
		Existing Method [29]	Proposed Method	Existing Method [29]	Proposed Method	Existing Method [29]	Proposed Method
1.	 horse.jpg	1.78	2.1	16.9	4.2	32.6	41.8
2.	 bhagat.jpg	2.2	1.8	13.5	1.07	32.7	47.8
3.	 boy.jpg	1.75	1.87	7.02	1.39	36.5	46.67

To analyse the system better, three comparative bar graph has also been prepared and shown below in

Figure 10-12.

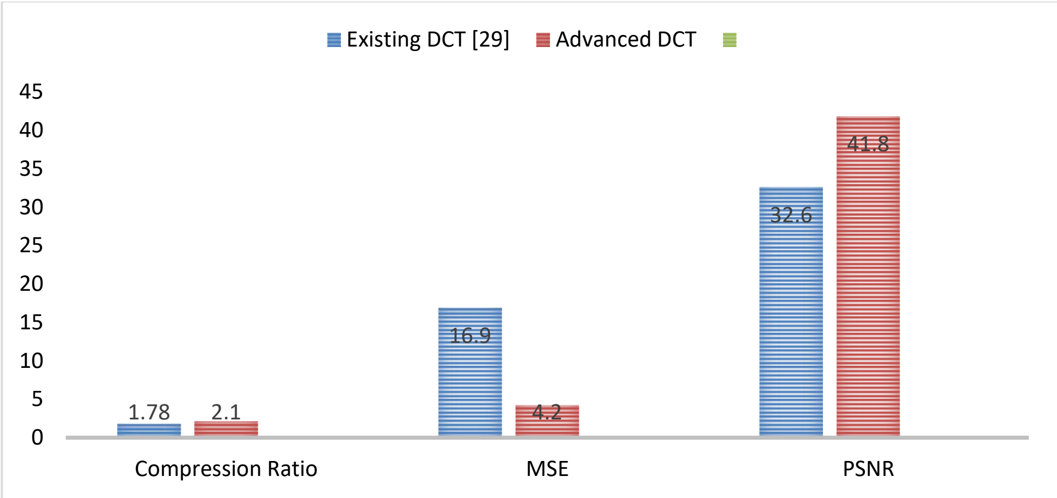


Fig. 10. Comparative analysis of existing and proposed method for different performance evaluation parameters for horse.jpg

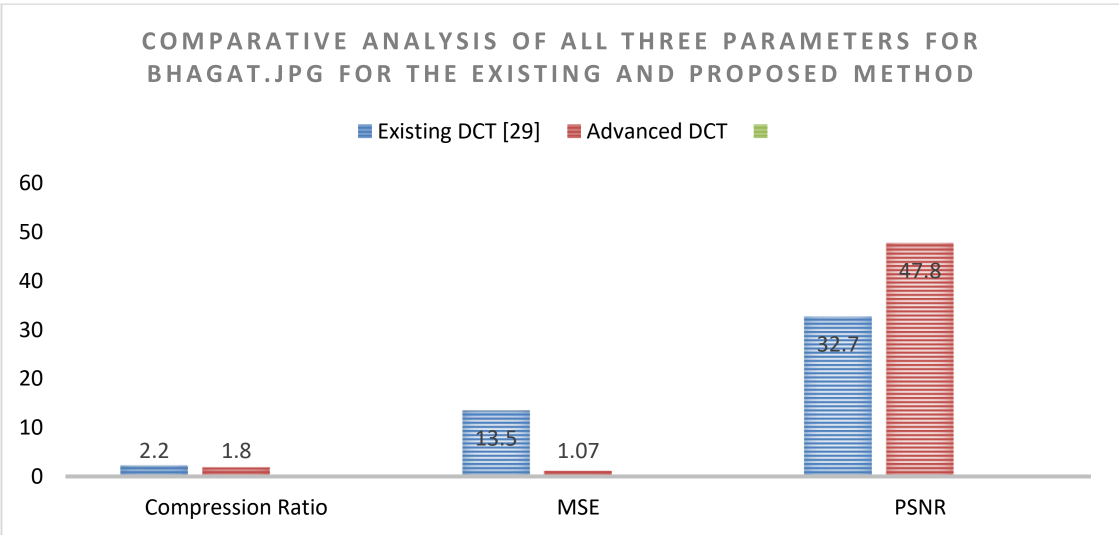


Fig. 11. Comparative analysis of existing and proposed method for different performance evaluation parameters for bhagat.jpg

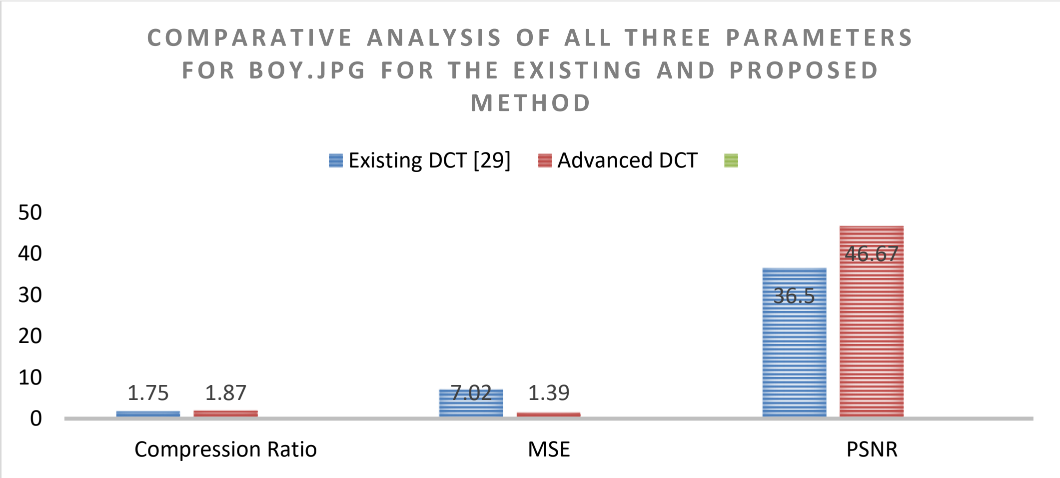


Fig. 12. Comparative analysis of existing and proposed method for different performance evaluation parameters for boy.jpg

The proposed method is also compared with the existing DCT method using Compression Ratio parameter. Barbhuiya et al. [4] considered images for the experimental purpose. The compression ratio of color images has been given in the table below.

Table 4 Comparative analysis of Compression Ratio for images for the existing and proposed method

S. No.	**Image to be compressed**	**Original Image Size(bytes)**	**Compressed Color Image Size(KB)**			**Compression Ratio of Color image(%)**	
			DCT [4]	**DWT [4]**	**Proposed Method (DCT)**	**Existing Method[4]**	**Proposed Method (DCT)**
1.	House.png	171133	26.0	10.1	13.5	94.05	93.1
2.	Baboon.png	209905	46.8	19.2	21.4	90.86	91.5
3.	Barbara.png	667546	46.9	45.1	42.9	93.23	94.3
4.	Pepers.png	651027	41.0	38.5	35.0	94.85	95.2

It is evident from a detailed study of Table 3 & 4 that the proposed approach is significantly more effective and efficient for color image compression. The MSE and PSNR for all the images varied significantly, even though the CR is remarkably similar. The proposed method yields substantially higher PSNR and much lower MSE for a similar CR. This large discrepancy demonstrates the efficiency and usefulness of the proposed technique for color image compression.

V. CONCLUSION

Comparative performance analysis of two states of the art methods, i.e., SVD and DCT for color image compression, is given in this research work. To assess the effectiveness of the two approaches, the performance evaluation matrices, i.e., Size after Compression, MSE, PSNR, Normalized Co-relation, Compression Ratio, and % space-saving, have been taken into account. The compression ratio for the advanced DCT method ranges from 12.26 - 26.09%. By noticing both the performance evaluation parameters above and others, it can be concluded that the DCT method works very efficiently for color image compression compared to the SVD method. The proposed DCT method has also been compared with the existing DCT methodology. It was discovered that, despite having comparable CR, significantly less MSE, and substantially higher PSNR, the proposed method is still performing well. This means that not only does the proposed DCT approach outperform the SVD method, but it also outperforms the existing DCT method. Both advantages can be used in the future to create a hybrid compression technique for color images.

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