Block wise image compression & Reduced Blocks Artifacts Using Discrete Cosine Transform

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Abstract- Image compression with DCT, quantization encoding method transform coding is widely used in image processing technique, however in these transformations the 2-D images are divided into sub-blocks and each block is transformed separately and into elementary frequency components. There frequency components (DC & AC) are reducing to zero during the process of quantization which is a lossy process. In this paper we are discussing about the image compression techniques with DCT and quantization method for reducing the blocking artifacts in reconstruction. The proposed method applies to several images and its performance is further analyzed for the reduction in image size. The picture quality between the original image and reconstructed image measured with PSNR value with different quantization matrices.

Index Terms- Discrete Cosine Transformation, Quantization Matrix, Image Processing, PSNR

I. Introduction

Data compression is defined as the process of encoding the data using a representation that reduce the overall size of the data. This reduction is possible when the original dataset contains some type of redundancy. Compression is a process to represent the image in less number of bits. This property is helpful to storage and transmission the data over internet. In the past decade many aspects of digital technology have been developed specifically in the fields of image acquisition **[**1, 3, 5**],** Data storage and bitmap printing compressing. The original image is significantly different from the compressing raw binary data image which has certain statistical properties. Encoders specifically designed for them provide the result which is less then optimal when using general purpose compression programs to compress image **[**19**].** One of many techniques under image processing is image compression which has many applications and plays important role in efficient transmission and storage of images **[**14**]**. Digital image compression is a field that studies different methods for reducing the total number of bits required to represent an image with good picture quality. This can be achieved by eliminating various types of [1] redundancy that exist in the pixel values. The transform coding is widely used in image compression and getting more and more attention day by day [4]. Compression is useful to reduce the cost of extra use of transmission bandwidth or storage for larger size images. Hence from this we can reconstruct a good accession of the original image in accordance with human visual perception

The rapid growth of digital imaging application, including desktop publishing, multimedia, teleconferencing and high definition television has increased. Hence the needs for effective and standardized image compression techniques are still required. The discrete cosine transformation which is a close relative as the DFT large dominate role in image compression [2]. The discrete cosine transform works to separate images into parts of different frequencies in quantization process where part of compression actually occurs, the less important frequencies are discard hence the use of the term 'lossy', so that the only most important frequencies those remain are used to retrieve the image in the decompression process.

DCT is used to map an image space into a frequency. DCT has many advantages like it has the ability to peak energy in the lower frequency for the image data and also it has the ability to reduce the blocking artifact effect where the boundaries between sub images become visible. The DCT de-correlates image data. Therefore due to this each transform coefficient is encoded independently without losing compression efficiency.

The Discrete cosine transform (DCT) is a method for transforms an image from spatial domain to frequency domain. In this paper, we are presenting a lossy discrete cosine transformation (DCT) compression technique for two-dimensional images. In the several scenarios, the utilization of the proposed technique of image compression results the better performance, when compared with the different modes of lossy compression. Here we also propose the reconstruction technique of image that models compression and exploits the quantization step size information in reconstruction. The proposed algorithm allows us to use the statistical information about the quantization. The framework is especially designed for the popular discrete cosine transformation (DCT) based compression method in which the linear transformation is involved. The proposed method of DCT based coding partitions the images into small square blocks (4x4, 8x8, 16x16, & 32x32) and then DCT is obtained over these blocks to remove the local spatial correlation. The substance of these specifications is to remove the considerable correlation between adjacent picture elements to reduce the visible blocks. After applying the DCT, the quantization process in applied to reduce the redundancy of the data. At the decoder end, the received data is decoded, de-quantized, and reconstructed by Inverse DCT. The proposed technique of DCT transformation provides three important result related to image quality to perform the analysis of the proposed technique like Peak to signal nose ratio (PSNR), mean square error (MSE) and compression ratio (CR) from gray images. The simulation and implementation of the proposed technique is performed in MATLAB.

II. Discrete Cosine Transform

The DCT is regarded as a discrete-time version of the Fourier-cosine series [6, 12, 20]. Hence, it is considered as a Fourier-related transform similar to the Discrete Fourier Transform (DFT), using only real numbers. Since DCT is real-valued, it provides a better approximation of a signal with fewer coefficients.

$$f(u,v) = \frac{2}{N} C(u)C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{\pi(2x+1)u}{16}\right] \cos\left[\frac{\pi(2y+1)v}{16}\right] \ldots\ldots\ldots\ldots\ldots (1)$$

$$for\ u = 0,1,2 \ldots\ldots\ldots N-1, and\ v = 0,1,2 \ldots\ldots\ldots . N-1$$

$$C(k) = \begin{cases} \frac{1}{\sqrt{2}}\ for\ k = 0 \\ 1\ otherwise \end{cases}$$

The process of decomposing a set of block (8×8) into a scaled set of a cosine basis function is discrete cosine transform. The process of reconstructing the set of samples from the scaled set of cosine basis function is called the inverse discrete cosine transform. This can describe as:

$$\mathrm{f(x,y)} = \frac{2}{\mathrm{N}} \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} C(u)C(v)\, f(u,v) \cos\left[\frac{\pi(2x+1)u}{16}\right] \cos\left[\frac{\pi(2y+1)v}{16}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$for\ x = 0,1,2 \ldots\ldots\ldots N-1, and\ y = 0,1,2 \ldots\ldots\ldots . N-1$$

The DCT is similar to the discrete Fourier transform it transforms a signal or image from the spatial domain to the frequency domain.

III. DCT based image compression

The DCT is a fast transformation method that takes an input and transforms it into linear combination of weighted basis function, these basis function are commonly the frequency, like sine waves. DCT compression seems to work better than the discrete Fourier transform method possibly because it allows smoother transitions between adjacent blocks. We know that be the DCT uses lower spatial frequencies with respect to DFT. The DCT transform is generated by dividing the pattern into square blocks and then reflecting each block about the $x \times y$ axes [6, 8, 11, 9]. A DCT block is a group of pixels of an 8×8 window. DCT grid is the horizontal and vertical lines that partition an image into blocks for the compression. After computation of image compression the IDCT algorithm is used to generate reconstructed image. The 2-D DCT transform applied separately to each block, irrelevancy reduction is then applied to the resulting transform coefficients of each block such that the most relevant information is retained for transmission or storage while the rest is eliminated **[**17, 5, 15**,** and 18**].** The DCT transforms the images of block size (4x4, 8x8, 16x16, & 32x32) pixels and the DCT is typically restricted to this size rather than taking the transformation of the image as a whole, the DCT is applied separately to blocks of the images. The DCT coefficients for each block are quantized separately by discarding the redundant and information high-coefficients. After transformation the image is applied for quantization method and receiver decodes the quantized DCT coefficients of each block separately and computes the 2D-IDCT of each block and then puts the blocks back together into a single image. The image file size is also reduced by dividing the coefficients into a quantization matrix. De-quantized and compressed image is reconstructed by using Inverse discrete cosine transformation although there is some loss of quality in the reconstructed image. It is recognizable as an approximation of the original image. The whole procedure is presented in figure 2.

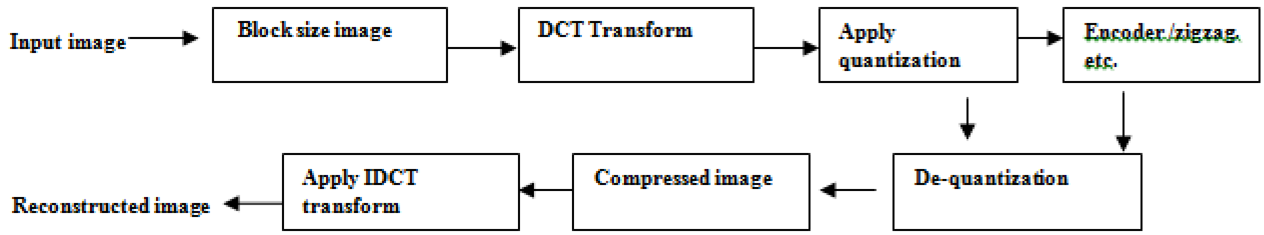


Fig.-02 Block diagram for image compression using DCT and IDCT

The 8x8 image block uses a set of 64 two-dimensional cosine basis functions that is created by multiplying horizontally oriented set of one-dimensional 8 point cosine basis function by vertically oriented set of same functions [15]. The horizontally oriented set of cosine coefficient represents the horizontal frequencies and the other set of coefficients represents the vertical frequencies. An N×M matrix image transform to DCT an 8×8. The transform of DCT is applied to each row and column. Images are separated into part of different frequency by the DCT as seen the figure 03. Each block of 8*8 is converted to a frequency domain representation using a 2D- DCT.

Original image **Fig.-03** **DCT apply transform image**

The coefficient with zero frequency in both dimensions is called the DC coefficients and the remaining 63 coefficients are called AC coefficients. The DC value is a sum over the whole image coefficients. The DC [17, 16] is a term of the horizontal basis which stored to the left of the output matrix whereas DC is a terms vertical basis function stored at the top. Thus, the top left corner of the matrix is the DC coefficients. The DC coefficients are of low bit rates, so that many high-frequency coefficients are rejected and the quantization of the DC coefficients generally causes the mention level of each block within a quantization interim. The 8 X 8 matrix of the original image can represent in table 1 and the table 2 presents the 8 X 8 matrix of the same image after applying the DCT method.

143	142	140	139	138	139	140	140
141	140	139	138	137	138	139	140
139	138	137	136	136	138	139	140
137	137	136	135	136	138	139	141
138	137	137	136	137	138	141	141
141	140	139	138	139	138	141	143
145	144	142	141	141	140	143	144
148	146	145	143	142	143	144	144

Table-1 Original image matrix (8×8)

The signal energy lies at low frequencies. It appears in the upper left corner of the DCT as shown above in table 2 [11, 9]. Therefore the compression is achieved with lower right values those represent higher frequencies.

DC coefficients ↘ AC coefficients ↘ AC coefficients ↙

191.8750	18.1593	0.6253	0.3499	-0.1250	-0.0455	-0.1237	-0.2295
-11.8915	-12.2765	6.6924	-0.2246	0.0982	0.4984	-0.5590	-0.2612
-6.8943	-7.5500	0.1616	0.1920	0.0676	0.1283	-0.6402	0.1063
-7.2842	-0.0503	0.0227	-0.1053	-0.1734	-0.0789	0.4131	-0.2923
0.1250	-0.5161	0.0280	-0.2169	0.1250	0.4564	0.3943	0.4071
0.1669	-0.0613	0.6044	-0.1521	0.0345	0.0425	0.6549	-0.5074
0.0144	0.0938	0.1098	0.2190	-0.1633	0.0115	0.3384	0.0187
-0.2606	0.1656	0.2227	0.4587	0.1470	0.1289	0.0957	-0.1607

Table-2 after apply DCT transform method in image pixel value (8×8)

IV. QUANTIZATION

Quantization is the process of reducing the number of possible value of quantity. Quantization is achieved by compressing a range of [7, 13**]** values to a single quantum. It gives the value when the number of discrete symbols in a given stream reduced the stream image compressible. Quantization is done by dividing each of the DCT coefficients by a quantization coefficients value and then rounding off the resulting value to an integer. Higher quantization coefficients value produces more compact output data but the quality of image degrades because of the DCT values are represented less accurately. It allows varying levels of image compression and quality through selection of specific quantization matrix. Thus quality levels ranging from 1 to 100 can be selected. This allows to greatly reducing the amount of information with high frequency components. This can implement by simply dividing each component in the frequency domain by a constant for that component, and then rounding the nearest integer. This is the main loss operation in the whole process. Thus, it is typically the case that many of the higher frequency components are rounded to zero and many of the rest become small number, which take many fewer bits to store**.**

V. IMPLEMENTATION & SIMULATION DESIGN

In this implementation & simulation design we transformed the whole image by DCT to all image pixels and image pixels size divided in 8×8 blocks. Now, the DCT is applied to each row and columns of the each 8×8 pixels block of an image. A DCT operation on this image provides very good frequency image with low spatial details. These transformed images provide very good energy computation in the low frequency region. In this image compression method, after applying DCT and dividing the image into 8×8 blocks the second step of quantization starts. The quantized object reduces most of the less high frequency DCT coefficients to zero. These more zeros will produce the higher image compression & lower frequencies and used to reconstruct the image. Higher frequencies are discarded by the quantization matrix recommended for luminance data (gray scale image) low frequencies in the upper left and higher frequencies in the lower right. Sub blocks in the source encoder exploit some redundancy in the image data in order to achieve better compression. The transformation sub-blocks de-correlates the image data thereby reducing (& in some case eliminating) inter pixels redundancy. The principal advantage of image transformation is the removal of redundancy between neighboring pixels. The quantization is to discard coefficients with relatively small amplitude without introducing visual distortion in the reconstructed image. DCT exhibits excellent energy computation for highly correlated images. The equation for generating the quantization matrix (QM) can represent as:

$$\mathrm{QM}\ (i,j) = (1 + (i + j) * Q) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where Q is the quality factor with value ranging from 1 to 100. Quality (Q) indicates the loss of data after compression. Higher value of the quality factor Q makes the coarser quantization and more loss of the information are in the image. Thus, high values of Q produce images with worse quality but more compactness. The number of coefficients used in this scheme is determined by using a performance metric for compression. Furthermore, a simple differencing scheme is performed on the coefficients that exploit correlation between high energy DCT coefficients in neighboring blocks of an image as shown in table 3.

31	46	61	76	91	106	121	136
47	62	77	92	107	122	137	152
63	78	93	108	123	138	153	168
79	94	109	124	139	154	169	184
95	110	125	140	155	170	185	200
111	126	141	156	171	186	201	216
127	142	157	172	187	202	217	232
143	158	173	188	203	218	233	248

Table-3 Quantized matrix (QM)

Each 8×8 DCT block is divided by quantization matrix and produces a resultant matrix which is nearest to the zeros value. All higher- frequency components will be rounded down to zero as shown in figure 4 and table 4.

$$quantized\ matrix(i,j) = round\left(\frac{DCT(i,j)}{QM(i,j)}\right) \dots\dots\dots\dots\dots (4)$$

6	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Table-4 Quantization matrix apply after quantization formula

After apply quantization matrix image

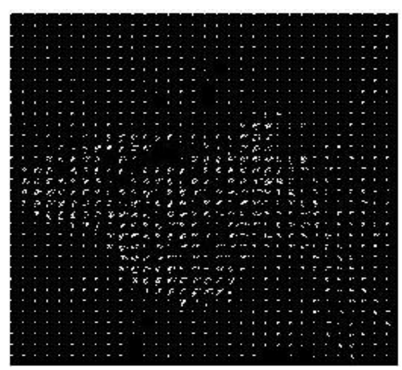


Fig.-04 After apply quantization matrix (Block wise) transformed image

De-quantization process works in reverse manner as IDCT. The image is reconstructed after the De-quantization process. De quantization which maps the quantized value back into its original range (but not its original for precision) is achieved by multiplying the quantized matrix with DCT transform matrix (i, j) as shown in equation 5 and table 5.

$$dequantization = quantized\ matrix(i,j) \times DCTmatrix(i,j) \dots\dots\dots\dots\dots\dots\dots (5)$$

186	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

Table-5 De-quantization matrix

Process of de-quantization is performed on each 8×8 block. During de-quantization process each quantized element is multiplied with corresponding element of quantized matrix and is rounded off block. After de- quantization process we have applied IDCT transformation to reconstruct the compressed image. It is observed that the original image of size 10.8 kb is compressed to 6.73kb after applying improved method as shown in figure 5 and table 6.

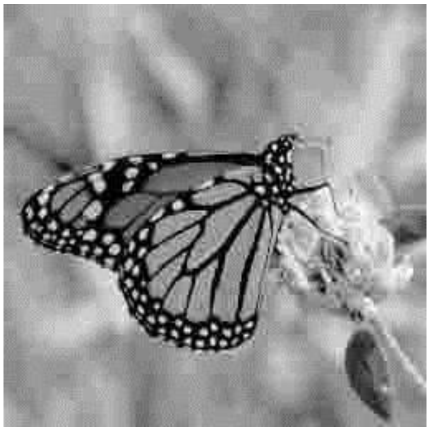


Fig-05 Reconstructed image after apply IDCT

140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140
140	140	140	140	140	140	140	140

Table-6 Reconstructed image matrix

VI. Results & Discussion

In the proposed implementation we considered the gray scale images of sizes (128×128, 256×256 & 512×512). The images are subdivided into 4×4, 8×8, 16×16 & 32×32 blocks and transformed with DCT. Each DCT coefficient was near to 8-bit precision. The DC coefficients are integers in the range of [-128,127]. The AC coefficients are integers of interval [0, 256]. To evaluate the performance of image compression we used MSE (Mean Square Error), PSNR (Peak Signal Noise Ratio) and compression ratio (CR) as:

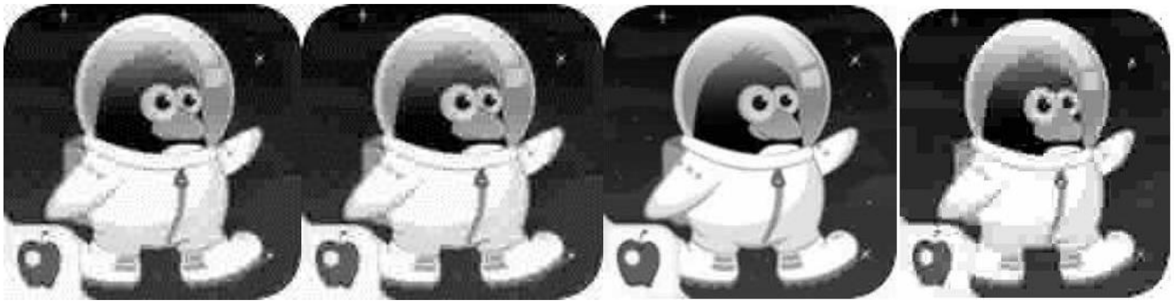
$$MSE = \frac{1}{m,n}\sum\sum\left(X_{i,j} - Y_{i,j}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where X is original image, Y approximation of decompressed image and m, n are dimensions of the image.

$$PSNR = 20 * \log_{10} (\frac{255^2}{MSE} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

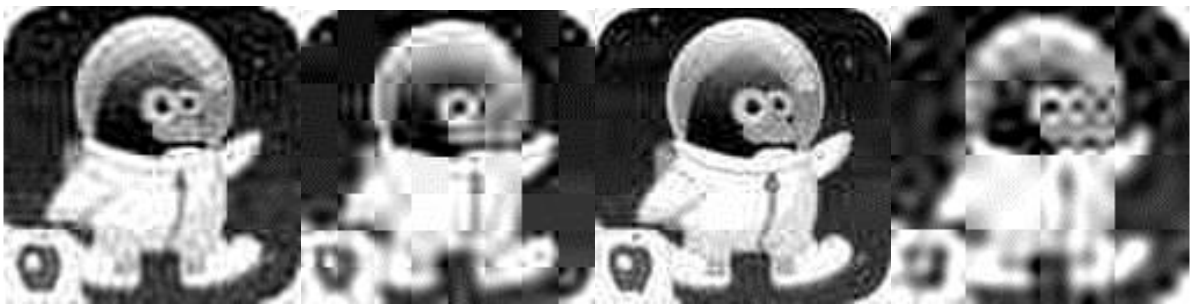
$$CR = \left(\frac{\text{Orignal image size} - \text{Reconstructed image size}}{\text{Orignal image size}}\right) \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

In this simulation the DCT Transformation has been applied with quantization on the images to compress the images. These methods are applied on the gray scale images of resolution size 128×128, 256×256 & 512×512. This transformation transformed the images after subdividing the images in the different block sizes. Performance is analyzed by reconstructing these images into same size of blocks. The performance is majored on the basis of three parameters i.e. PSNR, CR & MSE. The first experiment applied on an image of resolution size (128×128). The image is subdivided into blocks of 4×4, 8×8, 16×16 and 32×32. The performance of reconstructed image quality is considered after applying the DCT with quantization & inverse DCT. The obtain quantization matrix was applied corresponding to block size of image. The experiment results indicate that image after the DCT transformation is subdivided into the block size (4×4) for compression after applying quantization matrix and if quantization value (10) is increased step by step to keep block size fixed then reconstructed image picture quality shows that the PSNR, MSE & CR values becomes 31.6416db, 44.457 & 2.4 respectfully. Further if the quantization matrix is multiplied by 20 then PSNR, MSE & CR becomes 27.8629db, 106.3622 & 2.4. It is also observed that if quantization matrix is increased after multiplying by 50 then PSNR, MSE & CR values become 23.3885db, 298.0070 & 8.53 respectively. The reconstructed image quality can see in figure 6(a) & 6(b). Now if image is subdivided into the 8×8 block and same procedures applied as described above, then PSNR and CR values become (if Q×10) 28.6520db & 25.6 respectively. If Q is multiplied with 20 then PSNR and CR values become 25.5273db & 40.26 respectively. If the maximum quantization value as set by the experiment is considered (Q×50) then PSNR & CR becomes 22.0002db & 55.2 respectively. Now if we increased the block size of image to 16×16 & 32×32 and applied the same process to reconstruct the images then the PSNR value decreases but compression ratio and MSE error are increased as shown in result table-I, figure 6(a) and 6 (b).



Block size 4×4 Block size 8×8 Block size 16×16 Block size 32×32

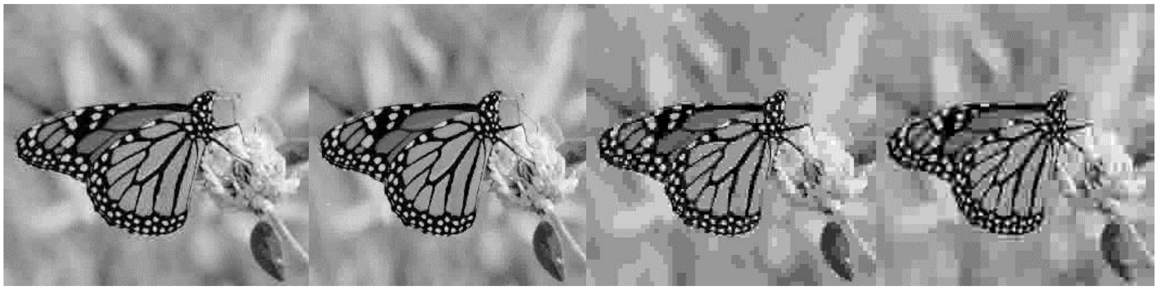
Fig.-06 (a) Minimum quantization matrix apply DCT & IDCT image reconstructed



Block size 4×4 Block size 8×8 Block size 16×16 Block size 32×32

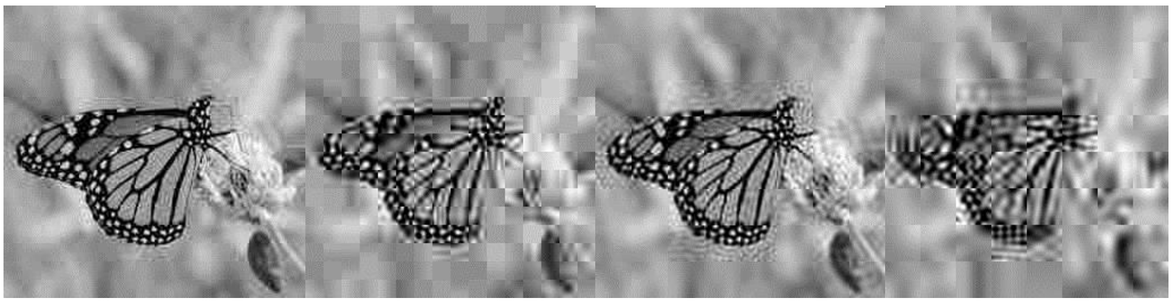
Fig.-06 (b) nm (128×128) Maximum quantization matrix apply DCT & IDCT image reconstructed

The second experiment applied on butterfly image of resolution size (256×256). The image is subdivided into blocks of 4×4, 8×8, 16×16 and 32×32. Performance is analyzed by reconstructing these images into same size of blocks. The performance is majored on the basis of three parameters i.e. PSNR, CR & MSE. The obtain quantization matrix was applied corresponding to block size of image. The obtain quantization matrix was applied corresponding to block size of image. The experiment results indicate that image after the DCT transformation is subdivided into the block size (4×4) for compression after applying quantization matrix and if quantization value is increased step by step to keep block size fixed then reconstructed image picture quality shows that the PSNR , MSE & CR values (seen result table-I) becomes 31.9516 db, 44.457 & 0.92 respectively. Further if the quantization matrix is multiplied by 20 then PSNR, MSE & CR becomes 28.3462db, 106.3622 & 2.77 respectively. It is also observed that if quantization matrix is increased after multiplying by 50 then PSNR, MSE & CR values become 24.0497db, 298.0070 & 5.55 respectively. The reconstructed image quality can see in figure 7(a) &7(b). Now if image is subdivided into the 8×8 block and same procedures applied as described above, (according result table-II) then PSNR and CR values become (if Q×10) 29.3524db & 29.35 respectively. If Q is multiplied with 20 then PSNR and CR values become 24.4702db & 46.38. If the maximum quantization value as set by the experiment is considered (Q×50) then PSNR & CR becomes 22.9886 db & 61.75 respectively. Now if we increased the block size of image to 16×16 & 32×32 and applied the same process to reconstruct the images then the PSNR value decreases but compression ratio and MSE error are increased as show in result table-II figure 7(a) & 7(b).



Block size 4×4 Block size 8×8 Block size 16×16 Block size 32×32

Fig.-07(a) Minimum quantization matrix apply DCT & IDCT reconstructed image



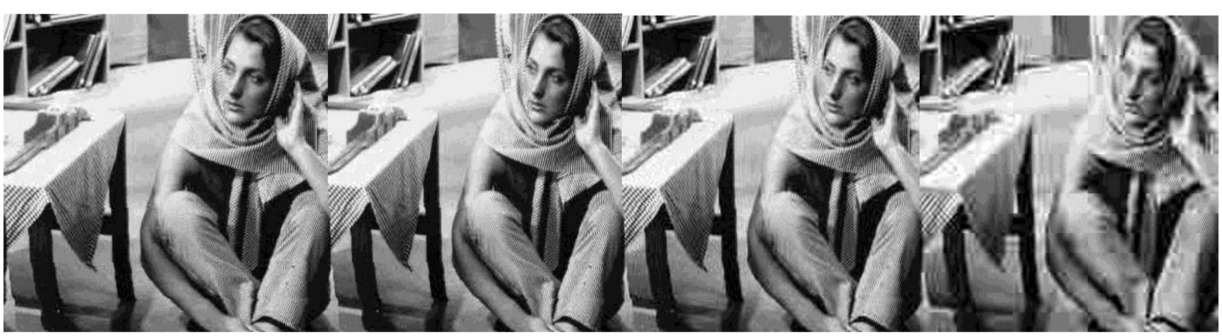
Block size 4×4 Block size 8×8 Block size 16×16 Block size 32×32

Fig.-07(b) Butterfly (256×256) Maximum quantization matrix apply DCT & IDCT image reconstructed

In the last stage of experiment we used a maximum resolution size image of Barbara (512×512). The image is subdivided into blocks of 4×4, 8×8, 16×16 and 32×32. Maximum dimension of image Barbara is divided into a maximum block size & compressed the image and we observed the reconstructed image quality as shown in figure 8(a) & 8(b). Now after obtaining the transformed image we analyzed the reconstructed image quality. Therefore if quantization matrix is multiplied with 10 then image quality PSNR values, coming maximum. Respectively Now if quantization matrix is multiply with 20 then image quality PSNR value are decreasing, but compression ratio CR & MSE values are increasing respectively, seen result table-III

Block size 4×4 Block size 8×8 Block size 16×16 Block size 32×32

Fig.-08 (a) Minimum quantization matrix apply DCT & IDCT image reconstructed



Block size 4×4 Block size 8×8 Block size 16×16 Block size 32×32

Fig.-08 (b)Woman (512×512) Maximum quantization matrix apply DCT & IDCT image reconstructed

Now if we increased the block size of image to 16×16 & 32×32 and applied the same process to reconstruct the images then the PSNR value decreases but compression ratio and MSE error are increase as show in figure 8(a) & 8(b). It is also observed that if block size is fixed for compressed image and the quantization matrix are increased step by step then the PSNR of reconstructed block size image decreases. It is also observed that when the quantization matrix assigns the maximum value then reconstructed image gets blurred because its MSE value increases.

VII. Conclusion

In this paper the technique of DCT and quantization is used to compress the images of different sizes. The inverse DCT is used to reconstruct the images on the varying block sizes i.e. 4×4, 8×8, 16×16, 32×32. The quantization matrix is constructed and increased until the best result is not obtained for reconstructed compressed images. The 256×256 size of butterfly image as shows above is reconstructed. This image is containing higher PSNR value among all the experiment with minimum error. It indicates that DCT compress the image with high quality when the original image is of 256×256 resolution size. It is also observed that the minimum quantization matrix is used for lossy compression to improve the picture quality. In this case the PSNR value becomes maxima with minimum CR and MSE values. The vice-versa results were also obtained if the maximum quantization matrix is used. The original image was reconstructed after DCT, quantization, de-quantization and IDCT with verifying the accuracy of implementation that reduce the blocking artifacts and simultaneously improve PSNR value of reconstructed image.

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