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An SVD Based Approach for the Removal of Artifacts from the Images Compressed by BDCT

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Abstract - Blocking artifacts continue to be among the most serious defects that occur in images and video streams compressed to low bit rates using block discrete cosine transform (BDCT) (e.g., JPEG, MPEG and H.263). In the proposed scheme a signal adaptive, space invariant & nonlinear filter is used to smoothen the DC sub image. The compressed image is divided into monotone & edge blocks based on the ac components present in each block. Then a Singular Value Decomposition filter is applied to the non edge blocks to remove the artifacts in the block. In the edge blocks the proposed filter is not applied since the artifacts in the blocks are not sensitive to human visual system. As a result real edges in the blocks are preserved. Finally corner outlier is detected and removed using an algorithm. This paper focuses to remove the blocking artifacts while preserving the real edges. In this paper new evaluation parameter DMSD is proposed. Experimental results shows that this proposed method is an efficient one to remove the blocking artifacts &to improve the quality of the image.

Index Terms - BDCT, blocking artifacts, image compression , postprocessing, ,SingularValue Decomposition

1. INTRODUCTION

Image data compression is a very important issue for many applications in the field of visual communications. The objective of image compression is to reduce irrelevance and redundancy of the image data in order to be able to store or transmit data in an efficient form while maintaining image quality. Many efficient image coding techniques have been developed for various applications and among them DCT based compression has been in use over a long period of time as a international standard for image and video compression. In a typical DCT compression scheme, the input image is divided into small blocks (typically 8×8), each block being transformed independently to convert the image elements to DCT coefficients. The DCT coefficients are then quantized using a scalar quantizer & all of the quantized DCT coefficients are encoded using variable length encoding. At the decoder end, the received data is decoded, de- quantized, and reconstructed by the Inverse DCT (IDCT).

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This block DCT scheme takes advantage of the local spatial correlation property of images and also saves processing time.

At high or moderate bit rates, the DCT coded image yields excellent reproduction without noticeable artifacts. However, at low bit rates ,the reconstructed images generally suffer from visually annoying artifacts . One major drawback in blocking artifacts which is due to the loss of correlation between adjacent blocks . Blocking artifacts are introduced by the coarse quantization of transform coefficients at low bit rates and the independent quantization for each block. There are three kinds of blocking effects in JPEG decompressed images. One is the staircase noise along the image edges, another is the grid noise in the monotone area, and the third one is the corner outlier in the corner point of the 8×8 DCT block. . The proposed post processing algorithm, which consists of three stages, reduces these blocking artifacts efficiently.

Nonlinear space variant filter [2] which adapts to the varying shape of the local signal spectrum & reduces only the locally out of band noise. It does not guarantee the smoothness of pixel values at either side of an edge. Here the classification is based on available edge information extracted from received blocky image. Thus the classification is inaccurate & hence the performance of this filtering scheme degrades . In [3] post processor is a combination of linear & non linear filter. The adaptation is achieved by changing filter coefficients according to the local characteristics of images & the blocking effects. Drawback of this method is computational complexity & no filtering is done at edge pixels. This filter used in [4] makes use of transform coefficients of shifted blocks ,rather than neighboring blocks. To characterize the block activity, human visual system(HVS) sensitivity at different frequencies is considered. This method is having high computational complexity. Since the filter is not shapeadaptive, grid noise cannot be smoothed out& the edge features got blurred.

Smoothing of areas with sharp transitions will not eliminate blockiness. In [5] DCT domain algorithm extracts all parameters needed to detect the presence and to estimate the blocking artifacts by exploiting the properties of human visual system(HVS).Block shifted domain filtering makes the process complex.

In [6] reduction of blocking artifacts in smooth regions of the image is taken into consideration. Here the correlation between the intensity values of the boundary pixels of two neighboring blocks in the DCT domain is used to distinguish between smooth and non-smooth regions. This technique preserves the edge information. In [7] a 2D multiple notch filter is used to reduce the blocking artifacts. Both nonlinear space-variant filtering and adaptive filtering schemes are used. It requires classification of image blocks, which is based on available edge information extracted from the received blocky image. Hence the performance degrades. A post processing algorithm to reduce the blocking artifacts in JPEG compressed images is given in [8] In this technique image is classified into edge area and monotone area according to the edge map. The signal adaptive filtering consists of a 1-D directional smoothing filtering for edge area and 2-D adaptive average filtering for monotone area. In [9] An over complete wavelet representation is used to reduce the quantization effects of block based DCT is given. Chou et al. remove blockiness by performing a simple nonlinear smoothing of pixels [10]. They first form the maximum likelihood estimation of quantization noise to differentiate between artificial and actual edges.

In this paper artifacts of reconstructed image is reduced using the following algorithms proposed .The quality of the image is measured using two parameters ie.PSNR & DMSD.The validity of the DMSD technique is discussed in section[IV].

In the section II.A, the non-linear, adaptive filter which is used in [1] is described in detail. In the second section SVD based algorithm in [1] is used with a modification. In the final section corner outlier detection & replacement filter in [11] is also used with a modification.

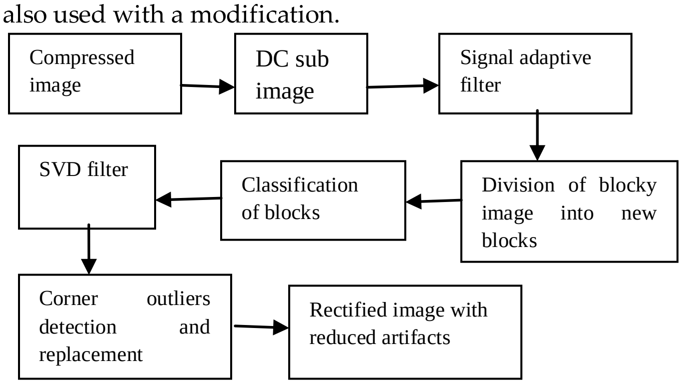

Fig : 1. Block diagram

2. PROPOSED METHOD

2.1.Post filtering of DC coefficients

In this method space variant, Non-linear, adaptive filter is used to reduce the discontinuities due to the DC coefficients. A signal adaptive filter is proposed to reduce both the grid noise in the relatively monotone area and the staircase noise along the image edge without any significant loss of the image details. In this Post filtering masking effect & adaptive filtering mechanisms are used.

2.1.1 Consideration of Masking Effect

For a good post processing method, it is desirable to efficiently reduce blocking artifacts and simultaneously to maintain image details. To measure the visibility of blocking artifacts, the masking phenomenon is considered here. Visibility of artifacts dependent on the local content of the given image. Due to the maskingeffect artifacts in regions of high activity are less perceptible than those in low-activity regions.The initial value of the mask at centre block of the image is taken as 0.75& the mask value of adjacent blocks of center block can be taken as 0.0625. The choice of a small neighborhood anda large weight set to the central component is to avoid blurring image details in those blocks of high activity These values which provides good results as compared to other .

2.1.2 Adaptive filtering mechanism

One of the factor of artifacts is due to the independent coding of blocks.So this filtering mechanism focuses on correlation among the blocks. Correlation within the blocks will differ depending upon whether it is monotone or edge. Classification of blocks can be done by comparing sum of absolute value of AC coefficients with a threshold. Threshold is average of AC coefficients. If the sum corresponding to center block is greater than threshold then the center block is considered as an edge block .In this case central will be given a weight factor 1 and surrounding blocks given a weight factor of zero otherwise center block is having the mask value 0.75 and surrounding blocks have 0.0625. If sum corresponding to the adjacent blocks is greater than threshold then it decreased to zero & the mask at the center block is increased by the same amount otherwise values remain unchanged. These values fed to the original & inverse DCT is taken.

2.2. Classification of blocks

This image is divided into the blocks in a manner in which the edges of the orginal image comes at the center of new blocks. Then the edges appears as high frequency components. This will help in reducing discontinuities due to these edges in the following SVD filter. Then the classification of blocks occurs which helps in processing blocks depending upon its activity. Blocking artifacts will appear more in low- activity blocks whereas it is less noticeable in high activity area.

2.3. Application of SVD filter

In this step block based, non-linear filter based on SVD [1] is used with a modification. One of the advantages of this technique is reduced computational complexity since the SVD is applied to each blocks & also it does not require any additional priori information. The singular value decomposition of an m×n real or complex matrix is of the form $M=U\sum V^*$,U is an m×m unitary matrix ,∑ is an m×n diagonal matrix with non negative real numbers on the diagonal,V*,an n×n unitary matrix . V*which denotes the conjugate transpose of the matrix of V.

$$M=U\sum V^*=\sum_{i=0}^{k} \alpha_i u_i v_i^T \qquad (1)$$

The diagonal entries of ∑ ie $\alpha_1,\alpha_2, \alpha_3, \alpha_4$….. are known as the singular values. These values are arranged in descending order. The m columns of U and n columns of V are the left singular vectors of M & right singular vectors of M. The number of non-singular values which represents the rank r of the matrix. Here the singular values can be divided into significant & non-significant singular values depending upon the value of threshold. The threshold which is the 5% of the largest singular value.

In the paper [1], the singular values which are less than a threshold is reduced to zero. But in this method singular values less than threshold value is a fraction (k) of actual SVD value This value is varied from zero to one. Consider a k×k block in the image. Calculate the SVD of this block using the equation (1). The value of non-significant singular values which can be varied as

$S(m,m)=k*s(m,m)$ (2) where k is a multiplication factor which is a fraction., s(m,m) which indicates singular values.

Calculate SVD for each block & reconstruct the image. The fraction at which best value of PSNR & DMSD (Discussed in section III) obtained is differing and it is varying with k for different images and is tabulated in table no:2

2.4 Corner outlier detection and reduction algorithm

Corner outlier is visually annoying artifact which appears in the form of stair case at the corner of the block. A corner outlier is characterized by a pixel which is much larger or much smaller than its neighboring pixels in the corner point of the 8 × 8 DCT block of the decompressed image.

In the filter [8], the pixel having corner outlier problem is considered to be only one third of the other adjacent corner pixels. Therefore when the pixel affected by corner outlier is much more than other adjacent corner pixels, this filter gives a distorted output. In the proposed paper, both these possibilities are considered and modified the algorithm as follows

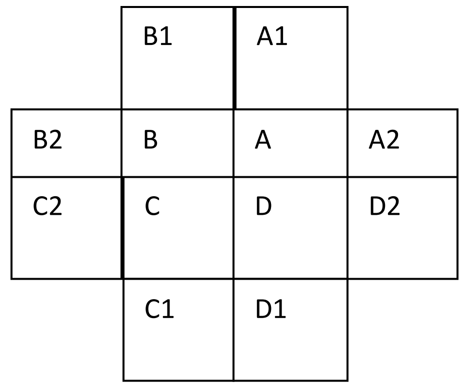

Fig : 2. Pixels used in corner outlier and reduction algorithms

Algorithm

Step 1:

if abs(A-C)>abs(B-D) & if abs(A-B)>abs(C-D) & if abs(A-C)>m&&abs(A-B)>m&&
abs(A- D)>m are satisfied, then
a=(A+B+C+D)/5

If A is less than all other corner pixels adjacent to it.
Then a=(2*A+B+C+D)/5
Then A is replaced by a.

STEP 2:

Then A1 and A2 are replaced by a1 and a2 where
a1=(2*A1+a)/3;
a2=(2*A2+a)/3;

Similarly this algorithm has to be followed for remaining corner pixel points B,C and D.

3. EVALUATION PARAMETER DMSD

The objective quality of the restored image is usually evaluated by the peak signal-to-noise ratio (PSNR). PSNR alone does not indicate the quality of the image. So a new measuring parameter difference in mean square difference (DMSD) is introduced in this paper.

DMSD is given by,

$$DMSD=(MSD_o-MSD_r)/MSD_o \qquad (3)$$

$MSD_o=\sum_{m=1}^{r}\sum_{n=1}^{c-1}[Io(m,n)-Io(m,n+1)]^2-\sum_{m=1}^{r-1}\sum_{n=1}^{c}[Io(m,n)-Io(m+1,n)]^2$ and

$MSD_r=\sum_{m=1}^{r}\sum_{n=1}^{c-1}[Ir(m,n)-Ir(m,n+1)]^2-\sum_{m=1}^{r-1}\sum_{n=1}^{c}[Ir(m,n)-Ir(m+1,n)]^2$

Where MSD_o denotes the mean square difference of the original image and MSD_r denotes the mean square difference of reconstructed image.

Five images are compressed at different compression rates using different quantization tables Q1,Q2,Q3,Q4 which given in the appendix.

From the PSNR and DMSD values tabulated in table no:1, it can be observed that as the quantization rate gets increased, the value of PSNR decreases & DMSD becomes more negative which indicates greater amount of artifacts.If the DMSD become more positive which indicates that the image is blurred. So image with high PSNR & with less negative DMSD indicates a high quality image. Figures 1(a),1(b),1(c) and 1(d) are the compressed images at various levels of quantization.

4. RESULTS & DISCUSSIONS

To evaluate the performance of this post processing algorithm, ,it has been applied to several jpeg compressed images. These images are compressed using DCT compression and encoded using non linear encoding. Various performance measures are used to evaluate the quality of the image. Two parameters used in this algorithm are PSNR & DMSD.

Peak signal to signal ratio(PSNR) is defined as

PSNR in db= $10\log_{10}(\max^2/MSE)$

$= 20\log_{10}(\max/MSE)$ (4)

Where max is the peak signal for 8 bit PCM and its value is 255.

PSNR in db= $20\log_{10}(255/MSE)$

MSE is mean square error given by

$MSE=1/N^2\left[\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}(rij-rij')^2\right]$ (5)

r_{ij} and r_{ij}' are the pixel values of orginal and decoded images at position (i,j).PSNR alone does not indicate the quality of the image.Here PSNR with DMSD is used to indicate the quality of the image.

In table no:2, results shows that DMSD and PSNR is varying with different values of k.This shows these two paramaters is a function of k. Fig 4, 5 and 6 indicates the processed images at different levels of algorithm. Fig:4 (a) is the decoded image using DCT after the process of compression.4(b) indicates the image after DC component filtering.This method shows significant reduction in blocking artifacts.This can be observed in Figures 5(a),5(b) and 6(a),6(b).It can be verified by the calculation of PSNR and DMSD values tabulated in table no:3 and 4.The improvement in PSNR and DMSD shows the reduction of artifacts. After the application of adaptive filtering, an SVD based filter is further applied to reduce the blocking artifacts.This can be observed in figures 4(c),5(c) and 6(c).PSNR and DMSD values obtained through the application of this filter is tabulated in table no:3 and 4.In the final stage,corner outlier detection and reduction algorithm is applied.This algorithm reduces the artifacts and corresponding PSNR and DMSD values are plotted in the table.The corresponding figures are 4(d),5(d) and 6(d).

4.1 Comparison of the performance with other algorithm

In table no:5 PSNR and DMSD values of the proposed algorithm and refrence [1] is tabulated .From the table,it can be observed that the PSNR and DMSD values are high as compared to the refrence[1].This shows that the proposed method is more efficient.

(a)

(b)

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(c)

(d)

Fig 3: Zelda image compressed at various quantization levels. (a),(b),(c),(d) indicates image compressed at respective quantization levels Q1,Q2,Q3 and Q4

TABLE 1

PSNR AND **DMSD** VALUES OF COMPRESSED IMAGES AT VARIOUS LEVELS OF QUANTIZATION

Image	Q1		Q2		Q3		Q4	
	PSNR	DMSD	PSNR	DMSD	PSNR	DMSD	PSNR	DMSD
Lena	34.0367	-0.1104	24.3973	-1.3859	19.8312	-3.2404	15.6162	-5.2383
Zelda	31.5980	-0.5631	25.5933	-1.4220	20.9960	-3.1124	17.3681	-3.4805
Clown	29.3381	-0.2142	22.9506	-1.2096	18.8371	-2.3566	15.4684	-3.4720
Goldhill	26.7900	-0.5013	22.0619	-1.1685	18.9326	-1.5296	16.3168	-1.5754
Crowd	27.9558	-0.0133	21.7209	-0.8239	17.6137	-2.0641	14.3869	-2.8279
Elaine	31.0743	-0.0389	24.5906	-0.7857	20.9488	-1.4127	17.1600	-2.2004

TABLE 2

VALUES OF **PSNR** AND **DMSD** WITH VARYING VALUES OF **K**

Image	k=0.1		K=0.3		K=0.5		K=0.8		k=0.9	
	PSNR	DMSD	PSNR	DMSD	PSNR	DMSD	PSNR	DMSD	PSNR	DMSD
Lena	33.6162	0.1181	33.9117	0.1186	34.0367	0.1104	33.8774	0.0819	33.7370	0.0680
Barbara	24.9167	-0.3774	25.0068	-0.3826	25.0171	-0.3954	24.8827	-0.4287	24.8002	-0.4435
Bridge	22.3199	-0.9015	22.3974	-0.9193	22.3663	-0.9634	22.1231	-1.0785	21.9949	-1.1300

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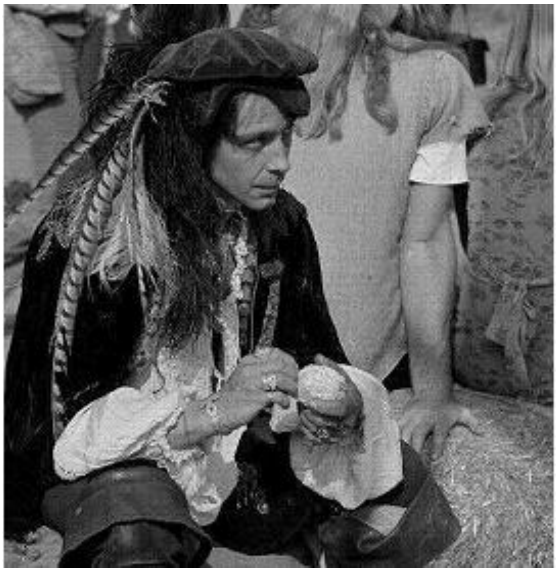


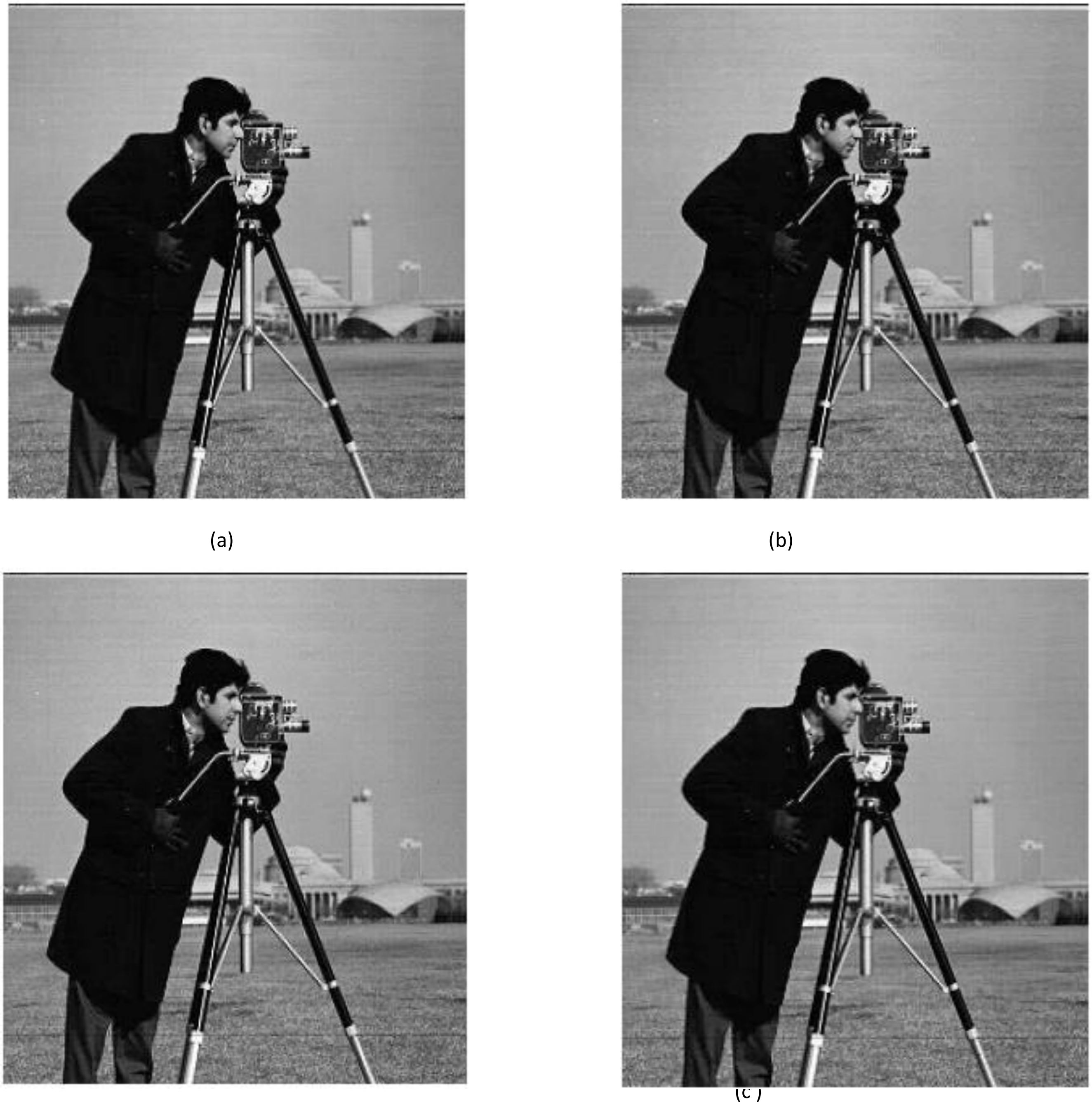
(a)

(b)

(c)

(d)

Fig 4: Result Man image at various levels of algorithm.(a) DCT compressed. (b) DC component filtering(c) SVD based filtering (d) With corner outliers reduction



(a) (b)

(c) (d)

Fig 5:Result Cameraman image at various levels of algorithm.(a) DCT compressed. (b) DC component filtering. (c) SVD based filtering (d) With corner outliers reduction

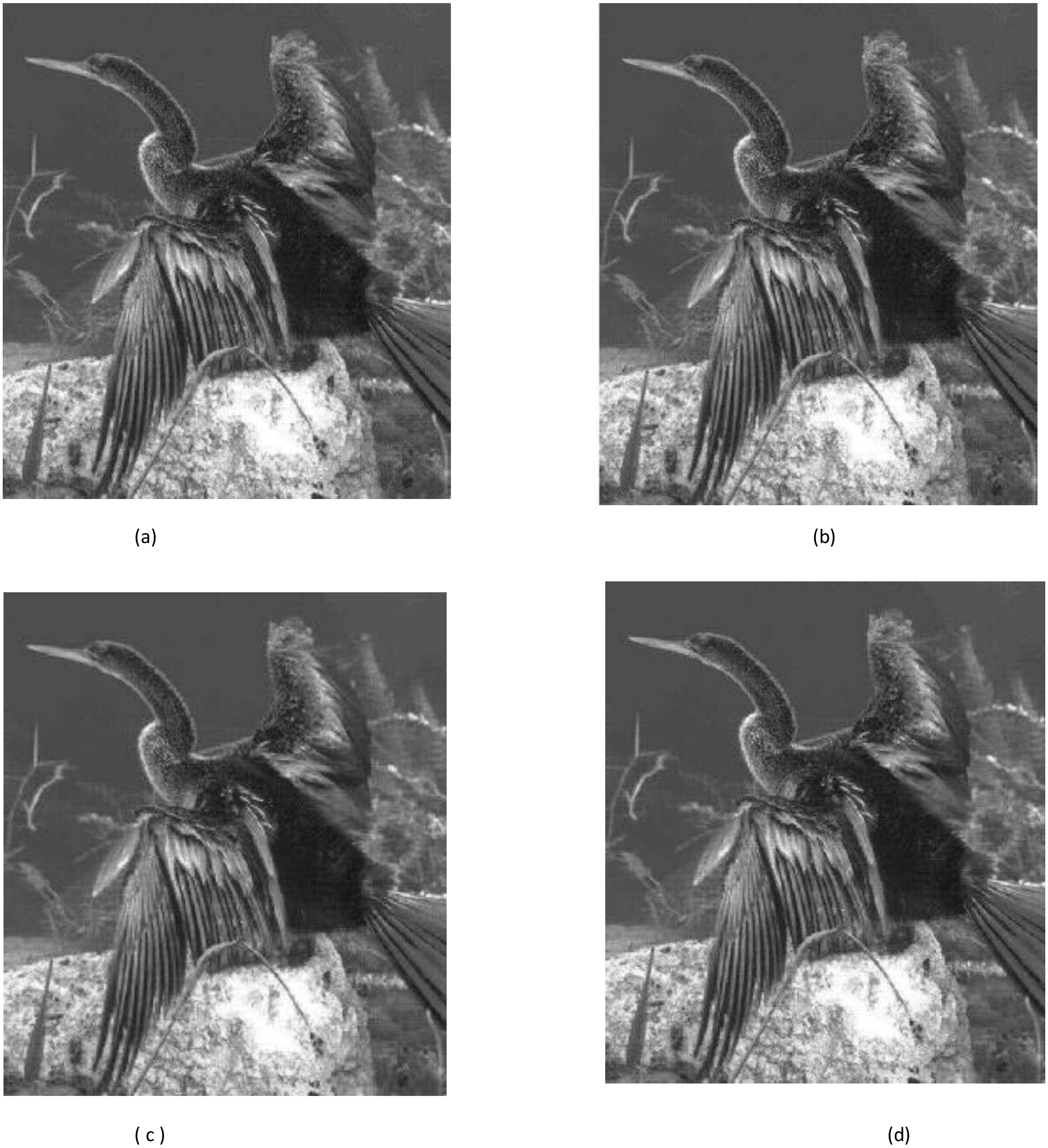


Fig 6: Result Bird image at various levels of algorithm.(a) DCT compressed. (b) DC component filtering.(c) SVD based filtering (d) With corner outliers reduction

TABLE 3

PERFORMANCE OF THIS ALGORITHM AT VARIOUS STAGES : **PSNR** VALUES OBTAINED USING DIFFERENT COMPRESSED IMAGES.

Image	Quantization Level	DCT coded	DC Component filtering	SVD based filter	Corner outliers reduction
		PSNR	PSNR	PSNR	PSNR
man	Q1	24.9550	24.9229	25.3386	25.3390
	Q2	18.7817	18.7820	19.0554	19.0580
	Q3	16.6836	16.7017	16.8282	16.8347
	Q4	14.2501	14.3010	14.3285	14.3454
cameraman	Q1	32.3170	32.2974	32.4565	32.3577
	Q2	22.3661	22.3762	22.6082	22.6051
	Q3	19.1067	19.1225	19.2255	19.2286
	Q4	15.6506	15.6860	15.7249	15.7487
Bird	Q1	23.3356	23.3289	23.6863	23.7014
	Q2	19.7434	19.7478	19.9997	20.0011
	Q3	16.8838	16.8946	17.0247	17.0316
	Q4	14.0819	14.0583	14.0906	14.1157

TABLE 4

PERFORMANCE OF THIS ALGORITHM AT VARIOUS STAGES :**DMSD** VALUES OBTAINED USING DIFFERENT COMPRESSED IMAGES

Image	Quantization level	DCT coded	DC Component filtering	SVD based filter	Corner outliers reduction
		DMSD	DMSD	DMSD	DMSD
Man	Q1	-0.4991	-0.4981	-0.3394	-0.3392
	Q2	-1.4181	-1.4171	-1.2893	-1.2856
	Q3	-1.2624	-1.2571	-1.1946	-1.1837
	Q4	-1.1988	-1.1809	-1.1658	-1.1425
Cameraman	Q1	0.3268	0.3279	0.3452	0.3349
	Q2	-0.9802	-0.9789	-0.8960	-0.8934
	Q3	-0.9558	-0.9536	-0.9143	-0.9068
	Q4	-1.5694	-1.5589	-1.5377	-1.5015
Bird	Q1	-0.8642	-0.8640	-0.7108	-0.7033
	Q2	-0.9752	-0.9747	-0.8727	-0.8718
	Q3	-1.3759	-1.3741	-1.3051	-1.2550
	Q4	-1.5195	-1.5046	-1.4769	-1.4383

TABLE 5

PERFORMANCE COMPARISON OF PROPOSED METHOD WITH REFERENCE [1]

Image	Quantization level	Proposed method		Reference[1]	
		PSNR	DMSD	PSNR	DMSD
Man	Q1	25.3390	-0.3392	24.9815	-0.4781
	Q2	19.0580	-1.2856	18.8011	-1.2901
	Q3	16.8347	-1.1837	16.7056	-1.2364
	Q4	14.3454	-1.1425	14,3012	-1.2022
Cameraman	Q1	32.3577	0.3349	32.2823	0.3794
	Q2	22.6051	-0.8934	22.4042	-0.9946
	Q3	19.2286	-0.9068	19.1283	-1.1032
	Q4	15.7487	-1.5015	15.6867	-1.7104
Bird	Q1	23.7014	-0.7033	23.3763	-0.8879
	Q2	20.0011	-0.8718	19.7596	-1.0538
	Q3	17.0316	-1.2550	16.8982	-1.2863
	Q4	14.1157	-1.4383	14.0586	-1.6879

5. CONCLUSION

In this paper a non-linear filter is used to reduce the difference in DC coefficients caused by compression. Then a SVD based approach is used to reduce blocking artifacts. The singular values less than threshold is replaced by a fraction of the original value. For various fractional valuesresults are computed and compared. Also Corner outlier is detected and reduced using a filter. It is observed that overall quality of the compressed image is improved using these three techniques

APPENDIX

QUANTIZATION TABLES

Q1

6	4	4	6	10	16	20	24
5	5	6	8	10	23	24	22
6	5	6	10	16	23	28	22
6	7	9	12	20	35	32	25
7	9	15	22	27	44	41	31
10	14	22	26	32	42	45	37
20	26	31	35	41	48	48	40
29	37	38	39	45	40	41	40

Q2

20	24	28	32	36	80	98	144
24	24	28	34	52	70	128	184
28	28	32	48	74	114	156	190
32	34	48	58	112	128	174	196
36	52	74	112	136	162	206	224

80	70	114	128	162	208	242	200
98	128	156	174	206	242	240	206
144	184	190	196	224	200	206	208

Q3

50	60	70	70	90	120	255	255
60	60	70	96	130	255	255	255
70	70	80	120	200	255	255	255
70	96	120	145	255	255	255	255
90	130	200	255	255	255	255	255
120	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255

Q4

110	130	150	192	255	255	255	255
130	150	192	255	255	255	255	255
150	192	255	255	255	255	255	255
192	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255

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