BLOCKING ARTIFACT DETECTION METHOD FOR HIGHLY COMPRESSED IMAGES

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Abstract—Blocking artifacts severely reduce the visual quality of the image making it unpleasant to the viewer. Reduction of blocking artifacts is essential to render the compressed image or video acceptable to the human viewer. There is thus an obvious need for detecting these blocking artifacts in the low bit rate DCT based compressed images, as it plays an important role in the design, optimization and assessment of image and video coding systems. In this work novel algorithm based on modeling function for blocking artifact detection in compressed images is proposed. Our experiment results show that for all type of images, the proposed method detects blocking artifacts more accurately as compared to other post-processing methods/techniques and is very efficient and stable since the signal need not be compressed/decompressed.

Keywords: DCT, bit-rate, blocking artifacts, compression ratio, JPEG.

I. INTRODUCTION

Transform coding is the heart of several industry standards for image and video compression. In particular, the discrete cosine transform (DCT) is the basis for the JPEG image coding standard [1-3], the MPEG video coding standard [4], and the ITU–TH. 261 [5] and H.263 recommendation's [6] for real time visual communication. However BDCT has a major drawback which is usually called blocking artifacts. In order to reduce blocking artifact, measurement of blocking artifact is very necessary. Several methods have been proposed to measure the blocking artifacts in compressed images [7-14]. In [7], a model was obtained that gives the numerical value depending upon the visibility of the blocking artifacts in compressed images and thus requires original image for comparison with reconstructed image. In practice the original images will not be available. In [8] the blocky image is modeled as a non blocky image interfering with a pure blocky signal. Blocking artifacts measurement is accomplished by estimating the power of blocky signal. The weakness of [10] is to assume that the difference of the pixel value in block boundary is caused only by blocking artifacts. This assumption decreases computation complexity but the measured value does not confirm to truth for the two adjacent blocks with a gradual change in pixel value. In [11], [12] and [15] the variation of pixel value across block boundary was modeled as a linear function. This method is not accurate especially for the adjacent blocks with a large change of pixel value across the block boundary .In this paper we propose a blind but accurate measurement algorithm by taking into account that the change in pixel value across block boundary is large as compared to adjacent pixels as we more away across block boundary.

II. BLOCKING ARTIFACTS MEASUREMENT SYSTEM

Blocking artifacts are introduced in the horizontal and vertical directions. Consider two 8×8 adjacent blocks 'c_1' and c_2'.

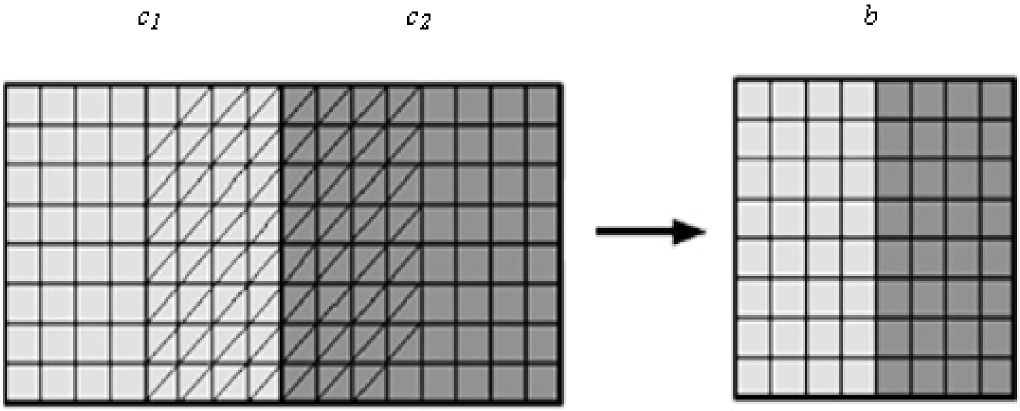


Figure.1: Illustration of constituting the new shifted block b.

Let the right half of 'c_1' and left half of 'c_2' as shown in Fig. 1 form a block denoted as block 'b'. Block 'b' is the 8×8 block which contains the boundary pixels. If any blocking artifacts occur between 'c_1' and 'c_2' the pixel value in 'b' will be abruptly changed. In this chapter a novel DCT domain method for blind measurement of blocking artifacts is proposed, by modeling the abrupt change in 'b'.

A. Existing Method by Park et al. [12]

The method proposed by Park et al. [12] assumed that the pixel values are gradually changed in the block boundary of the original image. Then, the original gradual change in block 'b' can be modeled as a 2-D linear function $l(x, y)$ given by

$$l(x, y) = l(y) = y - \left(\frac{N-1}{2}\right) \tag{1}$$

where x, y = 0. . . $N-1$. In (1), $l(x, y)$ is constant in the vertical direction and anti-symmetric in the horizontal direction as shown in Fig. 2.

B. Proposed Detection Method-I

The pixel-value difference across the block boundary can be regarded as the sum of the blocking artifacts and the pixel value change inherently existing in the original age. Assume that the change in pixel value across the block boundary is very large as compared to the variation in pixel value as we move away from block boundary.

Then the change in pixel value in block 'b' can be estimated as a function $f(x, y)$ given by:

$$f(x, y) = f(y) = \frac{y - \left[\frac{N-1}{2}\right] \pm 3.5}{2} \tag{2}$$

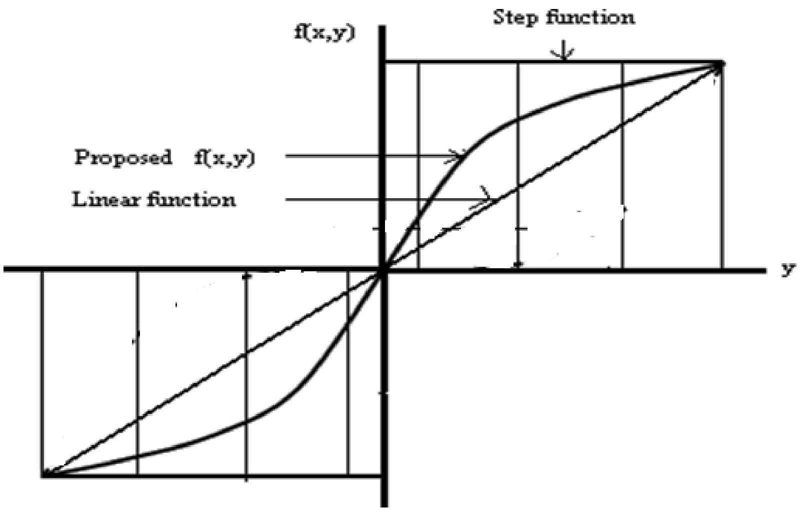


Figure. 2: Proposed and existing functions for blocking artifacts detection in the 1-D case

where $x, y = 0\ldots N\text{-}1$. In (2), $f(x, y)$ varies as shown in Fig. 2. The proposed function takes values between the step function and the linear function.

$$f(y) = \frac{y - \left[\frac{N-1}{2}\right] - 3.5}{2} \quad for\ y = 0,1,2,3 \tag{3}$$

$$f(y) = \frac{y - \left[\frac{N-1}{2}\right] + 3.5}{2} \quad for\ y = 4,5,6,7 \tag{4}$$

In the proposed method-I, it is assumed that the change in pixel value across the block boundary is very large as compared to the change in pixel value in the blocks. The flow chart of the proposed blocking artifacts detection algorithm is shown in Fig. 3.

The eight pixels values on the function $f(x, y)$ in case of proposed methods (I and II) can be obtained as:

$$k = \left[f(0), f(1), f(2), f(3) f(4), f(5) f(6), f(7) \right] \tag{5}$$

The 2-D 8x8 block '*g*' can be constituted by simply stacking the vector '*k*' row by row, i.e., the block '*g*' is anti-symmetric horizontally and constant in the vertical direction.

$$g = \begin{bmatrix} k_0 & k_1 & k_2 & k_3 & k_4 & k_5 & k_6 & k_7 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ k_0 & k_1 & k_2 & k_3 & k_4 & k_5 & k_6 & k_7 \end{bmatrix}_{8\times 8} \tag{6}$$

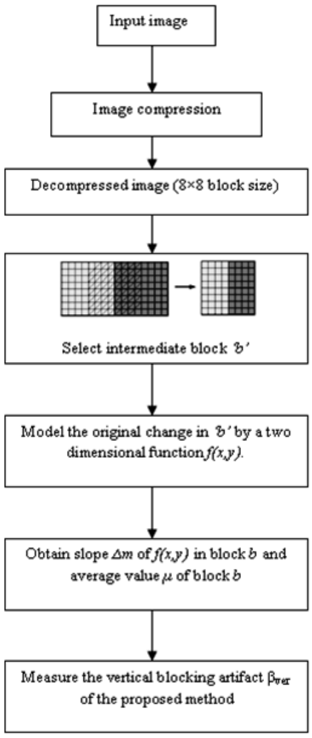


Figure. 3: Flow chart of the proposed vertical blocking artifacts detection algorithm

Therefore the, 8x8 DCT transform of '*g*' has only four non-zero elements in the first row. The blocking artifacts between blocks 'c_1' and 'c_2' can be regarded as a 2-D step function in the block '*b*' given by

$$s(x,y) = \begin{cases} -\dfrac{1}{N} \; for \; x = 0, \cdots 7 : y = 0, \cdots 3 \\ \dfrac{1}{N} \; for \; x = 0, \cdots 7 : y = 4, \cdots 7 \end{cases} \tag{7}$$

2.4 Estimating Slope of the 2-D Function

Let Δm be the slope of $f(x,y)$ and 'β' be the amplitude of $f(x,y)$. Then, block '*b*' can be modeled as:

$$b(x,y) = \mu + \Delta m.g(x,y) + \beta.s(x,y) + r(x,y) \tag{8}$$

where 'μ' is the average value of '*b*' representing local brightness and $r(x,y)$ represents the white Gaussian noise with zero mean as suggested by [11]. The average value 'μ' is given by:

$$\mu = \frac{\text{DC value of } b}{N} = \frac{f(0,0)}{N} \tag{9}$$

where '*N*' is block size which in our case is eight. Fig. 2 shows a 1-D model of the pixel value difference across the block boundary. Let the difference between two pixels in horizontal direction be denoted by:

$$m(x,y) = b(x,y) - b(x,y-1) \tag{10}$$

where $b(x,y)$ and $b(x,y-1)$ are the adjacent pixel values along the horizontal direction in block '*b*'

Let the slope of left half of '*b*' is Δm_L given by

$$\Delta m_L = \frac{1}{N}\sum_{x=0}^{N-1}\left[\frac{2}{(N-2)}\sum_{y=1}^{\frac{N}{2}-1} m(x,y)\right] \tag{11}$$

Let the slope of me right half of '*b*' is Δm_R given by

$$\Delta m_R = \frac{1}{N}\sum_{x=0}^{N-1}\left[\frac{12}{N(N-2)}\sum_{y=\frac{N}{2}}^{\frac{N}{2}-1} m(x,y)\right] \tag{12}$$

The slope Δm in block '*b*' can be computed by averaging Δm_L and Δm_R.

$$\Delta m = \frac{\Delta m_L + \Delta m_R}{2}$$

$$= \frac{1}{N}\sum_{x=0}^{N-1}\left[\frac{1}{(N-2)}\sum_{y=1}^{\frac{N}{2}-1} m(x,y) + \frac{6}{N(N-2)}\sum_{y=\frac{N}{2}}^{N-1} m(x,y)\right] \tag{13}$$

Once 'μ' and Δd are calculated the next part $\hat{b}(x,y)$ composed of $s(x,y)$ and $r(x,y)$ can be obtained by

$$\hat{b}(x,y) = \beta.s(x,y) + r(x,y) + \mu \tag{14}$$

$$= b(x,y) - \Delta m.g(x,y) \tag{15}$$

Using Equation (16), the blocking artifacts can be measured/estimated quantitatively.

III. FAST DCT DOMAIN ALGORITHM

The BDCT of 'c_1', 'c_2' and '*b*' are denoted respectively by C_1, C_2 and *B*. Let us define two matrices q_1 and q_2 as follows:-

$$q_1 = \begin{pmatrix} O & O_{4\times4} \\ I_{4\times4} & O \end{pmatrix},\ q_2 = \begin{pmatrix} O & I_{4\times4} \\ O_{4\times4} & O \end{pmatrix} \tag{16}$$

where *I* is Identity matrix and *O* is zero matrix

$$\therefore \hat{b} = c_1 q_1 + c_2 q_2 \tag{17}$$

In DCT domain, equation can be written as:

$$\hat{B} = C_1 Q_1 + C_2 Q_2 \tag{18}$$

The 8x8 BDCT transform of the block $c_k(x,y)$ is given by:

$$c_k(u,v) = c_u c_v \sum_{x=0}^{7}\sum_{y=0}^{7} c_k(x,y) \times \cos\left[\frac{\pi(2x+1)u}{16}\right] \times \cos\left[\frac{\pi(2y+1)v}{16}\right] \tag{19}$$

where k = 1, 2 and

$$c_u = c_v = \begin{cases} \sqrt{\frac{1}{8}} & for\ u=0, v=0 \\ \sqrt{\frac{2}{8}} & otherwise \end{cases} \tag{20}$$

Assume that the variation in pixel value of c_k is modeled by $\Delta m_k . f(x,y)$ here Δm_k represents the slope of function $g(x,y)$ in c_k . For $u = 0$ and $v=1$ substituting $\Delta m. f(x,y)$ for $c_k(x,y)$ in Equation (19) gives:

$$c_k(0,1) = \frac{\sqrt{2}}{8}\sum_{y=0}^{7}\Delta m_k . f(x,y) \times \cos\left[\frac{\pi(2y+1)}{16}\right] \tag{21}$$

where for proposed method-I

$$f(x,y) = f(y) = \frac{y - \left[\frac{N-1}{2}\right] \pm 3.5}{2} \tag{22}$$

$$c_k(0,1) = \eta \Delta m_k \tag{23}$$

Where η = -18.2241 according to [12]. Then, by averaging the slopes of 2-D function $f(x,y)$ in C_1 and C_2 we estimate Δm as:

$$\Delta m = \frac{\Delta m_L + \Delta m_R}{2} = \frac{C_1(0,1) + C_2(0,1)}{2\eta} \tag{24}$$

The value Δm can be easily obtained by using the above Equation (26) with less computational complexity as only two DCT values are required. Let us denote the first row of the 8×8 BDCT transform of $g(x,y)$ by $\hat{k} = [k_0, k_1, \ldots, k_7]$. To find '$\beta$' we first compute block $\hat{B}$ as given below in Equation (25).

$$\hat{B} = \begin{cases} B(i,j) - \Delta m.k_j, & i = 0 \ and \ j = 1, \cdots 7. \\ 0 & i = 0 \ and \ j = 0 \\ B(i,j) & otherwise \end{cases} \tag{25}$$

Note that the 8×8 DCT transform of the 2-D step function defined in Equation (7) has only four none zero elements in the first row. Let the vector $v = [v_o, v_2, \ldots\ldots, v_7]$ be the first row of the 8×8 DCT transform of the 2-D step function, Then $v_o=v_2=v_4=v_6=0$. By the unitary property of the DCT we have:

$$|v|_2 = \sqrt{\sum_{i=0}^{N-1} v_i^2} = \sqrt{\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} s^2(x,y)} = 1 \tag{26}$$

Hence the parameter 'β' can be computed as follows:

$$\beta_{ver} = \sum_{j=0}^{7} v_j . \hat{B}(0,j) \tag{27}$$

$$= v_1\hat{B}(0,1) + v_3\hat{B}(0,3) + v_5\hat{B}(0,5) + v_7\hat{B}(0,7)$$

where 'β_{ver}' represents the vertical blocking artifacts. Horizontal blocking artifacts 'β_{hor}' can be measured by applying the same principles. Because of the sparseness of DCT coefficients in the DCT block, the proposed method is far more efficient than the conventional IDCT-DCT methods [8]. If the magnitude of the blocking artifacts $|\beta|$ is very small as compared to the original variation of pixel values across the block boundary then the blocking artifacts may not observed.

IV. RESULTS AND DISCUSSION

The proposed blocking artifacts detection algorithms were applied to test images such as Lena, Bridge, Peppers and Elaine; all of these images were compressed with the standard JPEG code at different bit rates. The original and JPEG compressed Lena, Bridge, Peppers and Elaine images are shown in Fig.4.

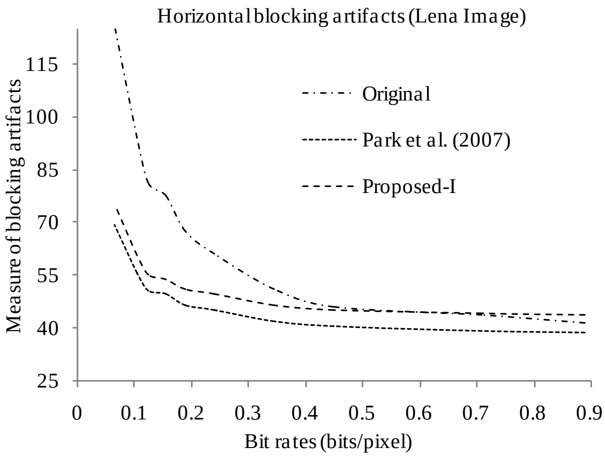
Figure 4: Original and JPEG compressed Lena, and Peppers image with blocking artifacts.

Table1: Comparison of blocking artifacts detection for different techniques applied to Lena image.

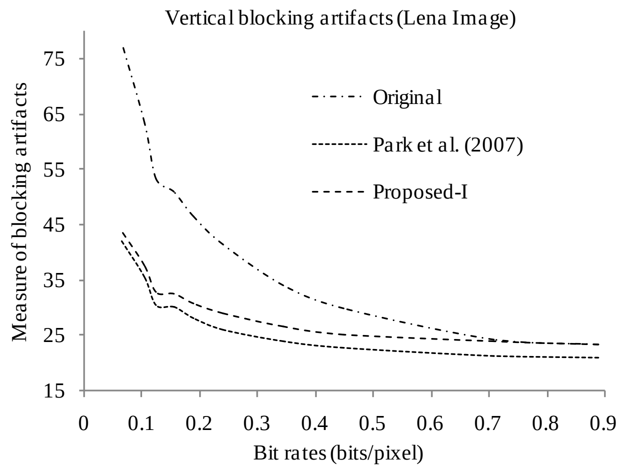
Lena Image	**Original**			**Park et al. [12]**			**Proposed-I**		
Bit rate	β_h	β_v	β_{av}	β_h	β_v	β_{av}	β_h	β_v	β_{av}
0.708	43.76	24.38	34.07	39.35	21.41	30.38	44.10	23.89	34.00
0.449	46.11	30	37.97	40.41	22.78	31.59	45.39	25.23	35.31
0.344	51.32	34.21	42.76	41.84	23.94	32.89	46.76	26.51	36.64
0.239	61.01	41.37	51.19	45.16	26.16	35.83	49.90	29.05	39.48
0.187	67.69	46.45	57.07	46.43	28.24	37.33	51.09	30.71	40.90
0.154	77.65	50.88	64.27	49.61	30.08	39.84	53.92	32.49	43.21
0.124	81.42	53.35	67.39	50.60	30.38	40.49	55.28	32.76	44.02
0.104	94.16	63.64	78.90	55.80	35.49	45.65	60.94	37.64	49.29
0.063	126.00	78.00	102.00	69.34	42.00	55.51	75.21	44.00	59.48

Table 2: Comparison of blocking artifacts detection for different techniques applied to Peppers image.

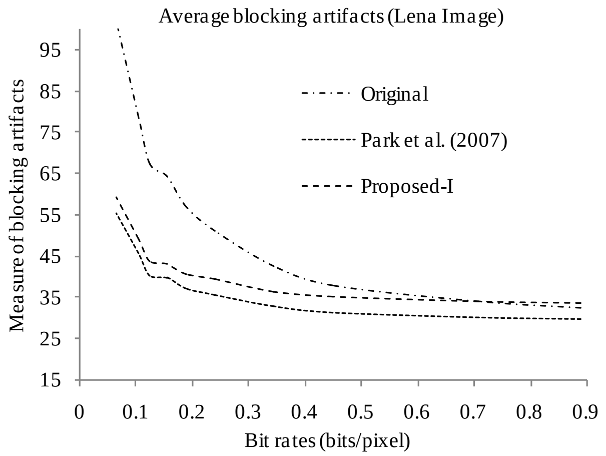
Elaine Image	Original			Park et al. [12]			Proposed-I		
Bit rate	β_h	β_v	β_{av}	β_h	β_v	β_{av}	β_h	β_v	β_{av}
0.947	33.19	33.93	33.56	26.89	22.17	24.53	29.87	24.65	27.26
0.457	36.70	34.43	35.56	28.05	23.75	25.90	31.42	26.5	28.96
0.314	42.59	38.64	40.61	29.95	25.83	27.89	33.22	28.92	31.07
0.208	50.96	47.25	49.11	33.63	29.41	31.52	37.45	32.78	35.11
0.158	60.82	57.65	59.19	37.05	33.81	35.43	40.45	36.87	38.66
0.131	66.94	63.77	63.35	40.05	36.14	38.09	43.81	38.90	41.35
0.103	76.09	70.38	73.23	44.03	39.26	41.65	47.96	42.42	45.19
0.084	81.37	75.99	78.86	46.46	41.88	44.17	50.08	44.66	47.37
0.030	106.0	91.12	98.65	60.00	53.00	57.00	65.00	56.00	61.00



(a)

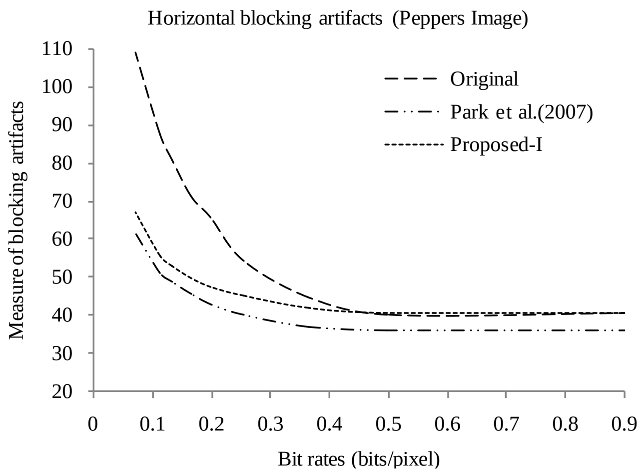


(b)

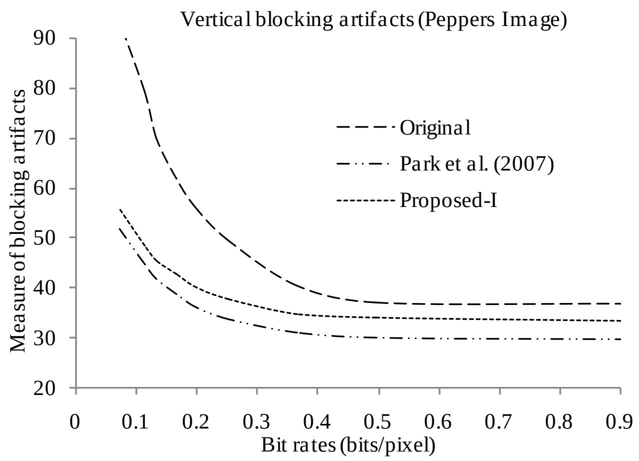


(c)

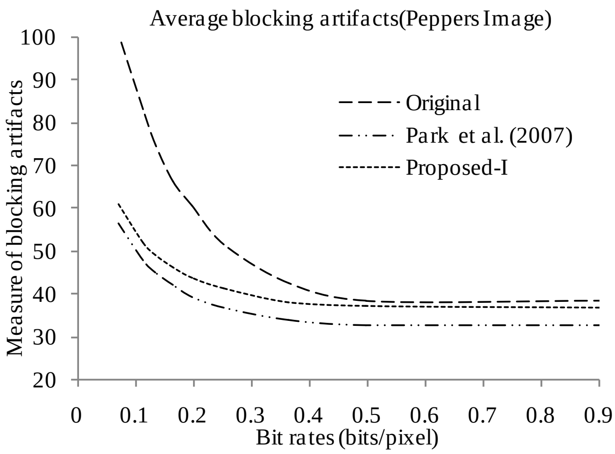
Figure.5: Comparison of horizontal (a) vertical (b) and average (c) blocking artifacts detection for different techniques applied to Lena image.



(a)



(b)



(c)

Figure.6: Comparison of horizontal (a), vertical (b) and average (c) blocking artifacts detection for different techniques applied to Peppers image.

Tables 1 to 2 present the experiment results of the blocking artifacts detection of the proposed method in comparison with the existing techniques for Lena, and Peppers images. Figs. 5-6 show the comparative results of the blocking artifacts measurement done by proposed method and the method proposed by Park et al. [12]. In addition, the results are also compared with true blocking artifacts. As shown in Fig. 5(a) the measured blocking artifacts (horizontal) of the proposed method gives better results as compared to other methods as bit rate is reduced from 0.70 the proposed method gives better results and the measured horizontal blocking artifacts 'β_h' of the proposed method is more close to true blocking artifacts as compared to the method by Park et al. [12]. Fig. 6(a) demonstrates that the proposed method detects blocking artifacts more accurately as compared to other methods as the bit rate is reduced from 0.90 bpp to 0.45 bpp for Peppers image. At lower bit rates the proposed method is a good choice for all type of images.

As shown in Figs. 5(b)-6(b) the measured vertical blocking artifacts 'β_v' of the proposed method gives better results and the measured 'β_{ver}' (vertical) of the proposed method is more close to true blocking artifacts as compared to the method by Park et al. [12]. Figs. 5(c)-6(c) shows the average blocking artifacts detection 'β_{av}' for different techniques applied to Lena, and Peppers image respectively.

V. CONCLUSION

A DCT-domain blind measurement of blocking artifacts methods are proposed, which are stable and can be applied to a wide variety of images in both pixel and DCT domain. In the proposed techniques the blocking artifacts are modeled as a function *f(x, y)* as shown in Fig. 2. compared to 2-D function proposed by Park et al. [12]. At lower bit rates (higher compression ratio) the method is good choice for all type of images. The proposed method may be used to improve the performance of existing algorithms used for reducing the blocking artifacts. The proposed blockiness detection method reduces the time and the computational load of the deblocking algorithms by having the deblocking algorithms applied only where needed. Due to its low computational cost, the technique may be integrated in to real- time image/video applications.

VI. REFERENCES

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