Reduction of Blocking Artifacts of DCT Compressed Image Based on Block Wiener Filtering

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Abstract

In this paper, a novel de-blocking algorithm is proposed, using block wiener filtering, shift and weighted average operations. The of block boundary occurs by a mixture of the shift and average operations. However, visually annoying artifacts are visible around the edge region in highly compressed images. In the proposed method, the wiener attenuation coefficients are given based on the expected error in a block unit. The hybrid DCT-Wiener-based (DCT-WB) interpolation scheme provides a powerful framework to interpolate an image by utilizing the information in both spatial and DCT domain. The DCT encoded images have a higher margin of error from one block to another. Hence texture information losses are prevented while smoothening effect is applied to the around the edge region. In examples, the proposed algorithm shows better performance than the before one.

I. INTRODUCTION

The discrete cosine transforms (DCTs) are applied as a basis for image and video coding standards for real time visual communications, such as JPEG [2] and MPEG [3]. Since images and videos are compressed using block-based DCT, such as JPEG, MPEG 2 and H.264/AVC, it is straight-forward to up-sample the image in the DCT domain. However, at low bit rates, encoded images generally suffer from visually annoying artifacts called a block noise. One of the major drawbacks of block-transform coding is the fact that it also introduces blocking artifacts due to quantization errors at the block boundaries. These artifacts are very noticeable and degrade image quality, particularly when images are compressed at a high compression rate. To deliver high-quality image compression using block-transform codes, the reduction of blocking artifacts is critical. The general technique was first introduced by Nosratinia with the re-application of shifted JPEG compressions [13]. This technique has since been modified for improved de-ringing [14] and it has been applied to wavelet coders to reduce compression artifacts [15].

Nosratinia's algorithm simply re-applies compressed procedure to the shifted versions of the already-compressed image, and average them with some weights. However, Nosratinia's method has two problems. The first problem is that its denoising power weaks on smooth region when a image is compressed at low bit rate. Moreover, a lot of shift operations are needed for best performance. If a block unit is 8×8 pixels, the shift amount is 64. In this paper, we tackle to overcome these problems by simple process.

We propose an algorithm to reduce the blocking artifacts based on a wiener filter. These artifacts appear as a regular pattern of visible block boundaries. This degradation is a direct result of the coarse quantization of the coefficients and of the independent processing of the blocks which does not take into account the existing correlations among adjacent blocks pixels. The wiener filter transforms images to be smooth, which is highly effective when difference between original images and compressed ones are large. In the proposed algorithm, the wiener filter [6], [7], used for decreasing a Gaussian noise, is modified to reduce the blocking artifacts. Our proposed method consists of the wiener filtering per a block, shift and the weighted average operations. The wiener coefficients are given by shape information based on the estimated error in block unit. The block wiener filtering prevents losses on texture information. Experimental results demonstrate that higher peak signal to noise ratio (PSNR) values are obtained if the block-sizes are reduced further which, however, contributes towards increased computational complexity. Accordingly, the proposed algorithm works well for the de-blocking of high compressed image. It is shown that the ideal Wiener DCT based filter potential is usually higher when noise variance is high. Under this process, we can decrease shift number compared to Nosratinia's method. In simulation, we have validated the deblocking performance in the enhancement of JPEG compressed images.

II. ALGORITHM FOR DE-BLOCKING USING DCT COMPRESSION

First, we introduce Nosratinia's de-blocking algorithm [1]. Let $\mathbf{X}(x, y)$ denote the original image, and let the DCT compressed image be given by **Y**(x, y) $q(\tau 2D(\mathbf{X}(x, y)))$.Where $q(\cdot)$, $\tau 2D(\cdot)$ are respectively a process of quantizing with quantization table **Q** and the process of 8×8 DCT. When **Y**(x, y) and **Q** are available, we want to obtain a reasonably good estimate$\hat{x}$ (x, y) of **X**(x, y). Let **H***m*(･) denote a shifting DCT **H***m*(･) = $\tau 2D$(shift(i,j)(･)). The process of *m*th alignment means the blocking image **Y**(x, y) is shifted in vertical and horizontal directions by (i, j), 1≤i≤8, 1≤j≤8, and the shifted images are transformed by DCT again. m is index of the selected pairs in totally 64 combinations. The DCT transformed coefficients of *m*th alignment are quantized.

$$\boldsymbol{c_m}\,(x, y) \;=\; H_M\mathbf{Y}(x, y) \qquad (1)$$
$$\hat{c}_m\,(x, y) \;= q(c_m(x, y)) \qquad (2)$$
$$\widehat{X}_m(x, y) \;= H_m^{-1}\hat{c}\;_m\,(x, y) \qquad (3)$$
$$\hat{X}\,(\mathrm{x,y}) \;\;=\; \frac{1}{m}\hat{x}_m(\mathrm{x,y}) \qquad (4)$$

where **C***m*(x, y), $\boldsymbol{\hat{C}_m}$(x, y) and $\boldsymbol{\widehat{X}_{\hat{m}}}$($x$, y) are respectively the transform coefficients due to **H***m*, the quantized coefficients and the *m*th de-blocked estimate of **X**(x, y). Then average all estimates so that the secondary blocking is diffused over all pixels. In fact, we can obtain the de-blocking image ˆ**X**(x, y). The quantization matrix can be used in same as the one used for JPEG compressed image. From a practical point of view, the quantization matrix is formed easily since it is represented in the original image. Near the image boundaries, the shifting operation needs to be adapted. We extend the images equally at boundaries. A number of shift operations M is full 64 or quincuncial 32 in Nosratinia's method.

III. PROPOSED DE-BLOCKING ALGORITHM VIA BLOCK WIENER FILTERING

For more effective de-blocking, we employ block wiener filtering approach. We find that it can improve the de-blocking effect, using the modified block wiener filtering, is more effective when block noise level becomes high. Therefore, Our algorithm attain to overcome the Nosratinia's drawback. Our proposed algorithm includes two steps as follows:

First step:

Obtain a first de-blocking image for the wiener filter. The algorithm is similar to reapplication of DCT in the preceding chapter. It is a shift cutdown version.

Second step:

Output the final denoised image. Second Step consist of almost exactly the same way as First Step. However, the quantizing processing is replaced with the wiener filtering which is derived from the first de-blocking image. Moreover the weighted average operation composes the final de-blocking image by combination of estimated images. We introduce the process of Second Step, consisted of the shifting operation, the wiener filtering and the weighted average. Second Step algorithm can be expressed by (5)-(7).

$$\boldsymbol{\mathrm{C}_m^{wie}(x, y)} \;\;= H_m\;\hat{x}(\mathrm{x,y}) \qquad (5)$$
$$\hat{c}_m^{wie}\,(x, y) \;\;= w_m(x, y)c_m^{wie}\,(x, y) \qquad (6)$$
$$\hat{x}_m^{wie}\,(\mathrm{x,y}) \;\;=\; H_m^{-1}\hat{c}_m^{wie}\,(\mathrm{x,y}) \qquad (7)$$

The wiener filter uses the frequency of first de blocking image **X**(x, y), and performs on block unit of 8×8 pixels. The shifting DCT **H***m* is applied to $\hat{x}(x, y)$ and obtain the truncated coefficients $\hat{c}_m^{wie}$ **(x,y)**with First Step. $w_m(x, y)$ is attenuating coefficients for the wiener filter. In this paper, a number of shifting operation is assigned M = 32 and M = 8. The shift operator in the case of M = 32 is identical with Nosratinia's one. If the shift number M is smaller than 32, we need to designate the shift operator to have better effect. When M = 8, we set the shift position (i, j) as diagonal (i, i) (1≤i≤8).

A. Block Wiener Filtering in 2D DCT Frequency

In second Step, the linear wiener filter is used instead of the quantization operator in First Step. The wiener filter contributes to more natural extension than quantizing technique. The proposed Wiener filter resolves the quarter-pixel shift issue and provides much better performance over the original 1D 6-tap pixel-based Wiener filter. Experimental results show that incorporating the proposed Wiener filter into the hybrid scheme improves the PSNR (0.44 dB).If an estimate of the true image is available, we can construct an empirical wiener filtering. The wiener coefficients are computed in 2D transform domain as follows:

$$\omega_m\,(xn, yn) = \frac{||c_m^{wie}\,(xn,yn)||\;\;^2}{\left||c_m^{wie}\,(xn,yn)\right|\;\;^2+\sigma_{m,n}^2} \qquad (8)$$

where x_n and y_n ($0 \le x_n \le 8$,$0 \le y_n \le 8$) are ordinate and abscissa in *n*th block of *m*th shifted image. *σm,n* is a variable depending on amount of the error in *n*th block of *m*th shifted image. The filter parameters may be optimized by the encoder and transmitted to the decoder, in order to maximize the PSNR of the reconstruction. With this approach, the best objective quality gains are always achieved, and we have the guarantee that the deblocking filter never degrades the image's PSNR. Specifically, the Wiener filter is computed using some training image pairs through the minimum mean squares error estimation. In our method, $\sigma_{m,n}$is decided by the local error estimation. An error in the DCT encoded images differ appreciably from one block to another. The estimated error **E**(x, y) is calculated from the first denoised image as

$$\mathbf{E}(x, y) = |\hat{X}\,(x, y) - \mathbf{Y}(x, y)|.$$

As a result, *σm,n* is defined as *σm,n* =8_x_n=1 $\boldsymbol{E_m}(x_n,\ y_n)$ (9) where $\boldsymbol{E_m}(x_n,\ y_n)$ = shift (i,j)(**E**(x, y)). The index m and selected pairs (i, j) are the same with ***Hm***(･) in(5).

B. Weighted Average :

The *m*th de-blocked estimate $\hat{c}_m^{wie}(x, y)$ is obtained *by the inverse transform of* $\boldsymbol{H_m}$*. The final de-blocked* image $\hat{x}_{wie}(x, y)$ is produced by combining the estimates $\hat{c}_m^{wie}$ (x, y) in each pixel as (10).

$$\hat{x}^{wie}(x_n, y_n) = \sum_{m=1}^{M} \gamma_{m,n} \, \boldsymbol{\hat{x}_m^{wie}}(x_n, y_n) \qquad (10)$$

$$\gamma_{m,n} = \frac{\mathbf{C_n}}{||w_n(x_n, y_n)||_2^2} \qquad (11)$$

where $\boldsymbol{C_n}$ is a constant independent of *m* chose10

$$\sum_{m=1}^{M} \gamma_{m,n} = 1$$

C. Implementation Algorithm:

The implementation algorithm is summarized as follows:
First Step

1) Obtain $c_m(x, y)$from $\mathbf{Y}(x, y)$ by frequency conversion of shifting block DCT (1). Shift position is optional.
2) Obtain $\hat{c}_m(x, y)$ by quantization of $c_m(x, y)$ for $m = 1, 2, \cdot \cdot, M$. The quantization table is the same one used for the compression.
3) Obtain the first estimated images $\hat{X}_m(x, y)$ from $\hat{c}_m$(x,y) by the inverse shifting block DCT.
4) Obtain the intermediate de-blocked image $\hat{X}(x, y)$ by average of overlapped estimates $\hat{x}_m^{wie}(x, y)$ of the same pixel naively.

Second Step

1) Obtain **C**wie *m* (*x*, *y*) from ˆ**X**(*x*, *y*) by the identical way with 1 of First Step.
2) Obtain the wiener attenuation coefficients *ωm*(*x*, *y*) from **C**wie *m* (*x*, *y*) and *σm,n* by (8). *σm,n* is calculated per block by estimated error of $|\hat{\mathbf{X}}(x, y) - \mathbf{Y}(x, y)|$.
3) Obtain $\hat{c}_m^{wie}$ (x, y) from $c_m(x, y)$ in 1 of First Step by wiener filtering.
4) Obtain estimated images $\hat{x}_m^{wie}$ (x, y) by the identical way with 3 of First Step.
5) Obtain the final de-blocked image $\hat{x}^{wie}(x, y)$ by the weighted average of overlapped estimates. The weight *γm,n* is computed from $w_m(n)$ per a block.
Fig 1: Test images

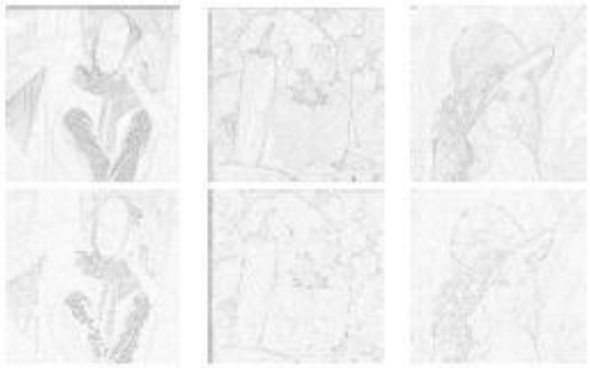
(a) Barbara (b) Pepper (c) Lena

IV. SIMULATION

In this section, we demonstrate the performance of the proposed algorithm. The test images are *Barbara*, *Pepper* and *Lena*, these standard 512 × 512 [pixel] 8-bit grayscale images (Figure 1). For de-blocking simulation ,these images are coded at different bit rate using the JPEG in MATLAB. We use the three quantization tables, these quality function (QF) are respectively 50, 20, 10. The proposed algorithm is used in condition on both shift quantity, *M* = 8 and *M*= 32. As the conventional method, the Nosratinia's method [1], which is a number of shift *M* = 32, are used. As a reference we have implemented Nosratinia's algorithm [4],a new and simple JPEG denoising method which re-applies JPEG compression to the shifted versions of the already compressed image, and computes the average. Despite its simplicity, following[4] this approach offers better performance than several other methods, including those based on nonlinear filtering, POCS and redundant wavelets. As an objective measure of the quality, we use the Peak Signal to Noise Ratio (PSNR). Table I gives the output PSNR values. Figure2 shows the details of the JPEG and enhanced images at QF=10. In high compression rate, the proposed method produces great improvement of PSNR. Both methods mostly removed the block noise in the de-blocked images.

However, we can find that the visual quality of around edge via our method is better than the conventional one Another major difference with the available Wiener filter is that the proposed Wiener filter is a block-based filter, which has a large block size of k×k, such that the estimated blocks overlap. In our experiments, we find that this novel structure is very beneficial to the performance of the class of fixed coefficients Wiener filter. In the next section, we will show the very highly competitive performance of the proposed Wiener filter. In the future, we will further analyze the performance of this block-based structure. The proposed method has better performance with less shift operator than the conventional method. Figure 4 shows error estimation results . The estimated error has a distribution somewhat similar to a true error. In addition, we can detect edge information because the edge regions in the DCT encoded image is more likely to have a large error. Figure 4 shows weights *γ*1,*n*.

We can conclude that our method improves the compressed image in PSNR and visual quality. The wiener filtering has powerful results for smoothening the rough parts of the compressed image. The weighted average process serve to reconstruct clearly the signal around edge.



(a) Barbara (b) Pepper (c) Lena

Fig. 3: Error estimation : (Top) true error, (Bottom) estimated error.

(a) Barbara (b) Pepper (c) Lena

Fig. 4: Weight $\gamma 1,n$ per block for the weighted average.

TABLE I: PSNR of de-blocked images in [dB]

Image	QF	JPEG	First Step		proposed algorithm	
			M = 32 [1]	M = 8	M = 32	M = 8
Barbara	10	25.79	26.55	26.34	**26.73**	26.69
	20	28.34	29.41	29.16	**29.54**	29.51
	50	32.88	34.02	33.72	**34.06**	33.98
Pepper	10	30.12	31.15	30.98	**31.39**	31.32
	20	32.42	33.21	33.06	**33.32**	33.28
	50	34.74	**35.24**	35.13	35.19	35.16
Lena	10	30.39	31.42	31.12	**31.60**	31.58
	20	32.94	33.81	33.62	**33.90**	33.86
	50	35.78	**36.45**	36.49	36.39	36.35

V. CONCLUSION

In this paper, we introduced a novel de-blocking algorithm , that has positive effects on noise removal of blocking artifacts. It can naturally improve signal in smooth region and around edge region while protecting edge and texture information. The proposed method is superior to the previous one in the improvement of PSNR value. We only need a DCT compressed image and a quantization matrix. It is also easier to use because it does not need to train or optimize approach. We can suppress the rise in calculation amount by reducing a count of shifting transformation.

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The 2013 International Conference on Advanced Technologies for Communications (ATC'13)

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