ABSTRACT:

Images coded at higher compression ratios mostly suffer from significant compression artifacts that degrade the visual quality of the images. These images degradation occur by the coarse quantization procedure of $8 \times 8$ discrete cosine transform (DCT) coefficients. In this paper, an adaptive postprocessing technique has been proposed to suppress the blocking artifacts that are generally occur in JPEG decoded images especially at low bit rates. Comprehensive experimental results illustrate that the proposed technique is more effective and stable for alleviating blocking artifacts with respect to existing techniques. Compared with other techniques, the proposed technique achieves better detail preservation and blocking effects removal performance with lower computational complexity.

Keywords—directional filter, blocking artifacts, pixel vectors, PSNR-B.

[1] INTRODUCTION

In recent years, the demand for image compression has grown steadily and it is a fundamental aspect of transmission and image storage. Due to limited storage capacity and channel bandwidth, mostly images are distributed over the network exist in low quality versions degraded from compression artifacts [1]. The most common image degradation occurs with reconstructed image by compression and downscaling. Compression reduces spatial and temporal domain in an image and downscaling further reduces spatial resolution. Both compression and downscaling can highly reduce the requirement of storage and bandwidth for images, but these components also lead to important information loss.
Several images and videos compression standards, such as JPEG, MPEG, H.161/263/264 etc use a block based discrete cosine transform (BDCT) to exploit the spatial correlation between adjacent pixels [2]. At the encoder side, an input image is usually divided into 8×8 block scheme; each block is transformed independently into frequency domain using BDCT. For each transformed block, DCT coefficients are compressed into a bitstream through quantization and entropy coding method. At the decoder end, an image is reconstructed by inversely transforming the quantized DCT coefficients extracted from bitstream. At moderate or high bit rates, the image coded by DCT generates an excellent reproduction without any noticeable blocking effects. On the other hand, the reconstructed image suffers from visually annoying blocking effects at low bit rates due to quantization effects. The blocking artifacts generally appear as artificial block boundary among neighboring blocks [3]. Compression algorithms can be classified into two categories: lossy and lossless. Lossless compression algorithm is known as error free scheme. The lossless compression technique is used to represent an image signal with minimum number of bits and preserves the information without any loss. Therefore, it requires small storage capacity and also speeding up transmission. Various applications require lossless technique such as Facsimile (FAX) transmission, medical imagery and satellite image compression where any loss of information can lead to be wrong diagnosis or prediction [4]. Lossy algorithm contains some loss of information and input data has been compressed by lossy methods that cannot be reconstructed or recovered exactly. Lossy techniques are adopted by multimedia applications because these require higher compression rates.

In order to reduce blocking artifacts while maintaining compatibility with aforesaid coding standard, several postprocessing methods have been designed. These methods include various filtering techniques such as theory of projection onto convex sets (POCS), estimation theoretic methods, wavelet based methods and adaptive deblocking filtering methods. In the first category, the original images are highly correlated as determined by [5] for the reduction of blocking artifacts. Due to highly correlated image, the global frequency features of two adjacent (8×8) blocks are identical to local ones in every block. An iterative deblocking technique for reduction of artifacts in BDCT coded images based on adaptive smoothness constraint sets, an intensity constraint set and adaptive smoothness constraints and intensity constraint [6]. These types of constraints are elaborate by the closed convex sets. An iterative process for coded images is projected iteratively to obtain a good quality of image with artifacts. The non-iterative postprocessing method is based on POCS using DCT for the complexity reduction in [7]. In D-POCS (DCT domain POCS), the Low-pass filtering (LPF) is operated in DCT domain. Therefore DCT and IDCT components are not required.
POCS based techniques have high computational complexity due to iterative nature. Therefore, these techniques are difficult to adapt by images and videos processing applications.

In second category, a deblocking block transformation compressed images using weighted sums of symmetrically aligned pixels are described in [8]. The weighted sums are determined empirically so it can be either linear or quadratic. When weights are assigned to an image and compressed at low bit rates the deblinking image is suffer from false edges near the original edges. These types of artifacts are called ghosting. A grading matrix has been proposed to reduce these new artifacts. To implement these types of techniques in real time applications, a high performance platform is required. A postprocessing technique for low bit rates based on maximum a posteriori (MAP) criterion has been proposed in [9]. Noise model is used to describe the distortion in the image which is caused by coding. The original image is dependence upon high order MRF which is based on field of expert’s framework. In third category, a wavelet based deblocking method which determines the difference between coefficients of entire image and wavelet transformation coefficients in high frequency component in different subbands and using various values and different strategies [10]. An adaptive threshold value is implemented to various images and different characteristics of blocking effects. The block size is 8×8, the decomposition level of wavelet transformation is one level. For whole image, the number of decomposition levels is three for wavelet transformation. The wavelet transformation is based on number of quasiinterpolatory splines and interpolatory. The proposed method is based on three steps: split, predict and update [11].

In forth category, an efficient DCT domain approach for blind measurement of blocking effects by two dimensional step functions in shifted blocks [12]. A DCT domain approach captures every parameter which is required to identify the presence of blocking artifacts by implementing human visual system (HVS) features [13]. To find the difference between smooth and non smooth region mode, the correlation among intensity value of block boundaries of two adjacent (8×8) blocks in DCT domain is determined. A frequency domain technique is used to identify the boundary region between the two adjacent (8×8) blocks with smooth or non-smooth region has been proposed in [14]. In the smooth region, blocking artifacts are removed by updating some DCT coefficients and a smoothing filter is applied to non-smooth region for edge preservation that is genuine edge. A new block boundary measure (BBM) index is implemented to both horizontal and vertical block boundaries. A signal adaptive filter for blocking artifacts is based on smooth, non smooth and intermediate regions [15-16]. An adaptive spatial postprocessing technique consists of thresholding value, mode classification and a 2-D filtering. The pixel vector model is classified into low activity model,
mid activity model and high activity model. A 2-D filter is able to remove the ringing artifacts near the edge regions [17].

In this paper, we proposed a novel adaptive postprocessing deblocking method for decoded images. According to threshold value, we implement different types of deblocking filters and reduce blocking artifacts, corner outliers and staircase noise effectively. 1-D filter is applied inside the block as well as on the block boundaries and 2-D directional filter employs for the whole image.

[2] PROPOSED DEBLOCKING TECHNIQUE

The proposed method is based on separate modes which have been designed for reduction of blocking effects in DCT compressed images. The proposed approach identifies each region of blocking artifacts and adjusts filtering strength for each region. The primary objective of the proposed algorithm is to remove the blocking effects as well as ringing artifacts from a coded image based on local characteristics of an image. The boundary area between two adjacent blocks is classified into smooth, intermediate and non-smooth region. The proposed method alleviates the blocking artifacts and preserves the image detail with small loss of image content.

A. Local Activity and Filtering Decision: After finding the PV with blocking effects, the choice of threshold is also important all over the algorithm. The selection of an appropriate threshold is prominent to extract the PV with blocking artifacts. Although, due to different degraded effect, all discontinuities at block boundary are distinct. With the consideration of these situations, here introduce a threshold adaptive to the statistic propriety of PV, which is:

\[ |\text{offset}| \leq T_k \]  

Where \( T_k = 155 \times QP^{0.09} \), \( \text{offset} = |p_2 - p_3| \)

Where \( p_2 \) and \( p_3 \) are pixel vector across the block boundary region as illustrated in fig 1. \( T_k \) is used as a threshold to determine 8x8 adjacent blocks with blocking effects, k notation extract from the kth pixel vector. The strength of blocking effect nearby the block boundary is evaluated by analyzing the pixel among two horizontally adjacent blocks or vertically adjacent blocks. It is known as block boundary activity (BBA) and it is donated by \( u(\alpha) \) is measured as:

\[ u(\alpha) = \sum_{k=0}^{4} [\varphi(p_k(i + 1) - p_k(i))] \]  

\[ \varphi(\Delta p) = \begin{cases} 
0, & |\Delta p| \leq \Psi \\
1, & \text{otherwise} 
\end{cases} \]

Where \( \varphi(\cdot) \) is the indicator function, \( \Psi \) is a threshold value which determines activity of neighboring pixels. After measuring, the five difference values with respect to Eq. (2) their sum is used to find an appropriate activity. If activity across the block boundary is low, this
determines a smooth region mode, while the high activity determines a non-smooth region mode. If the activity lies between low and high activity, the region is called moderate region mode.

**B. Smooth Deblocking Filtering:** If \( u(\theta) \) is smaller than \( T_1 \) than pixel vector belongs to smooth region mode. Smooth deblocking filtering has less complexity as compared to moderate and non-smooth region model. If the region has low frequency:

If \( |offset| < T_{SDF} \)  

Where \( T_{SDF} \) is threshold value for the normal region mode. Here, designed another threshold value \( T_{HV} \) to extract the pixel vectors with artifacts at a block boundary with constraint determined as:

\[
if \ |offset| \geq T_{HV} 
\]

If the above constraint is satisfied, then the pixel vectors are modified as Eq. (6). On the other hand, if above constraint is not satisfied, the pixel vectors are modified as Eq. (7). For simplicity, \( T_{HV} \) is set to \( 0.015T_k \).

\[
p_k'(i) = p_k(i) + \frac{offset}{a_i} , i = 0,1,...,N-3
\]

where \( a_i = \{8,6,2,-2,-6,-8\} \)

\[
p_k'(i) = p_k(i) + \frac{offset}{a_i} , i = 0,1,...,N-3
\]

Where \( a_i = \{-8,-6,-2,2,6,8\} \)

**Figure 1. Pixel vectors for calculating activity**
On the other hand, if the condition given in Eq (4) is not satisfied, a new filter with another threshold value to identify two types of low frequency model is added to further nature improve the visual quality as well as preserve the image detail. The proposed edge filter with a threshold value \( T_{SDF} \) where \( T_{SDF} = 0.11T_k \) is as given in Eq. (8).

\[
p'_k(i) = \begin{cases} 
  p_k(i) + \frac{2 \times \text{offset}}{1+\sqrt{8 \times \text{offset}}}, & \text{if } i = \frac{N}{2} - 2 \\
  p_k(i) - \frac{2 \times \text{offset}}{1+\sqrt{8 \times \text{offset}}}, & \text{if } i = \frac{N}{2} - 1 
\end{cases} \\
\text{where } i \in \{1,2,3,4\} \\
p'_k(i) = p_k(i) + \frac{\text{offset}}{a_i}, & i = 2,3 \\
\text{where } a_i = \{-10,10\}
\]  

(8)

C. Moderate Deblocking Filtering: If \( T_1 < u(v) < T_2 \) is satisfied, then the region is determined as moderate region mode. After calculating activity \( F(V) \), the two thresholds values, such as \( T_1 \) and \( T_2 \), are used to define the frequency modes. Experiments exhibit the settings as \( T_1, T_2, \Psi \) to 1, 3, 2 respectively. If \( \lvert \text{offset} \rvert < T_{MDF} \), the region is moderate frequency model and filter defined by equation’s (9) or (10) is activated, otherwise filter defined in Eq. (8) is activated. \( T_{MDF} \) is kept higher than \( T_{MDF}(T_{MDF} = 0.9T_k) \).

\[
p'_k(i) = \begin{cases} 
  \frac{1}{4} \sum_{h=0}^{i+1} p_k(h) 
\end{cases} \\
\text{where } i \in \{1,2,3,4\} \\
p'_k(i) = p_k(i) + \frac{\text{offset}}{a_i}, & i = 2,3 \\
\text{where } a_i = \{-10,10\}
\]  

(9)

(10)

D. Non Smooth Deblocking Filtering: If \( u(v) > T_2 \) is satisfied, then the region is considered as high frequency region. To remove over smoothing, across the block boundary, three thresholds \( T_{HV} \) (As earlier defined), \( T_{NSDF} \), and \( T_d \) are proposed. \( T_{NSDF} \) threshold for high frequency region and as used to analyse the edge filter by accepting edge threshold value and to preserve the true edges. If the difference between two adjacent pixels within block boundary is smaller than \( T_d \) then the adjacent pixel values are updated according to Eq.’s (12) and (13). If \( \lvert \text{offset} \rvert < T_{NSDF} \), the region is non smooth mode and the filter applies as defined in equation sets (8) and (11) with respect to the Eq. (4) are activated. Otherwise the filter is used as given in Equation’s (12) and (13) are activated. Parameters \( T_{NSDF} \) and \( T_d \) are defined empirically and determined as follows:

\( T_{NSDF} = 0.7T_k \) and \( T_d = 0.6T_k \) respectively.

\[
p'_k(i) = \begin{cases} 
  p_k(i) - \frac{2 \times \text{offset}}{1+\sqrt{8 \times \text{offset}}}, & \text{if } i = \frac{N}{2} - 2 \\
  p_k(i) + \frac{2 \times \text{offset}}{1+\sqrt{8 \times \text{offset}}}, & \text{if } i = \frac{N}{2} - 1 
\end{cases} \\
p'_k(i) = \begin{cases} 
  p_k(i) - \frac{2 \times \text{offset}}{1+\sqrt{8 \times \text{offset}}}, & \text{if } i = \frac{N}{2} - 2 \\
  p_k(i) + \frac{2 \times \text{offset}}{1+\sqrt{8 \times \text{offset}}}, & \text{if } i = \frac{N}{2} - 1 
\end{cases} \\
p'_k\left(\frac{N}{2} - 2\right) = \begin{cases} 
  \text{if } \left(\frac{N}{2} - 2\right) \leq T_d, \\
  \frac{p_k\left(\frac{N}{2} - 2\right)}{8} - \frac{\text{offset}}{8}, \\
  \frac{p_k\left(\frac{N}{2} - 2\right)}{8} + \frac{\text{offset}}{8}, & \text{otherwise}
\end{cases}
\]  

(11)

(12)
\[ p'_{k} \left( \frac{N}{2} - 1 \right) = \begin{cases} 
    p_{k} \left( \frac{N}{2} - 1 \right) - p_{k} \left( \frac{N}{2} \right) / \text{offset} & \text{if} \left| p_{k} \left( \frac{N}{2} - 1 \right) - p_{k} \left( \frac{N}{2} \right) \right| \leq T_d \\
    p_{k} \left( \frac{N}{2} - 1 \right) / \text{offset}, & \text{otherwise} 
\end{cases} \] (13)

**[3] DIRECTIONAL FILTER**

Mostly edge blocks are affected by ringing artifacts and corner outliers, which are very difficult to eliminate by using 1-D method. A 2-D directional filtering with respect to 3×3 mask is as shown in Fig. 2. Suppose \( f(\beta, \gamma) \) is the pixel to be filtered. Then the filtered output \( f'(\beta', \gamma') \) is obtained by using Eq. (14).

\[ f'(\beta', \gamma') = \sum_{(\beta', \gamma') \in W(\beta', \gamma')} w(\beta, \gamma) f(\beta' + \beta, \gamma' + \gamma) \] (14)

Where \( w(\beta, \gamma) \) is the weight function which is obtained by using the function of differences between the pixels as defined in Eq. (15).

\[
\begin{array}{ccc}
    f(\beta-1, \gamma-1) & f(\beta-1, \gamma) & f(\beta-1, \gamma+1) \\
    f(\beta, \gamma-1) & f(\beta, \gamma) & f(\beta, \gamma+1) \\
    f(\beta+1, \gamma-1) & f(\beta+1, \gamma) & f(\beta+1, \gamma+1) \\
\end{array}
\]

**Figure 2. A 3×3 mask for the 2D directional filtering for edge block**

\[ w(\beta, \gamma) = \exp\left(-\frac{1}{2} \left| f(\beta' + \beta, \gamma' + \gamma) - f(\beta' - \beta, \gamma' - \gamma) \right|\right) \] (15)

**[4] EXPERIMENTAL RESULTS**

In order to illustrate the performance of the proposed technique, it has been applied to JPEG decoded images. The test images in the experiments include popular images Lena and Cameraman as shown in Fig. 3(a-b).

**Figure 3. Test images**

To measure the efficiency of the proposed technique, three conventional techniques such as [15-17] have been implemented and the results are compared with the results using the proposed
Blocking Artifacts Suppression in Block-Coded Grey Scale Images Using an Adaptive Filtering

Method. The objective quality of decompressed image is evaluated by peak signal to noise ratio including blocking effects (PSNR-B) and mean opinion score (MOS) indices.

![Graphs](image)

**Figure 4. Comparison of PSNR-B and MOS results for Lena and Cameraman image**

Figures 4 (a-b) demonstrate the experimental results of PSNR-B generated by implementing the proposed technique in comparison with the conventional techniques in Ref. [15-17]. Figures 4 (a-b) exhibit that the proposed method gives best PSNR-B values as compared to all other methods for test images compared at different bit rates. Results demonstrate that the proposed technique outperforms all other methods [15-17] in terms of PSNR-B. Figures 4(c-d) present the MOS comparison for different post-processing techniques implemented to different JPEG compressed images. The proposed technique produces higher MOS values as compared to existing methods. The proposed algorithm does not only reduce all types of compression artifacts effectively, but also preserves image details very well.

[5] Conclusion

In this paper, we have been proposed an adaptive postprocessing method which alleviates the blocking effects for BDCT based images and also more effectively at low bit rates as illustrated in the results. The proposed method consists two parts: one is 1-D adaptive filtering and another is 2-D directional filtering. In the filtering procedure, we have designed three types of filters, such as smooth, moderate and non smooth deblocking and finally, directional filter is used to remove ringing artifacts, stair noise and corner outliers. To illustrate the performance of the proposed method, PSNR-B, MOS indices have been used. The proposed technique generates an
excellent image quality across a wide variety of images. Experimental evaluation of the proposed method clearly illustrated its capacity to recognize and alleviate the blocking artifacts effectively, while preserving the original detail of an image. Due to low complexity, the proposed method can be easily implemented in real applications and adaptive technique with good objective qualities.

REFERENCES


BLOCKING ARTIFACTS SUPPRESSION IN BLOCK-CODED GREY SCALE IMAGES USING AN ADAPTIVE FILTERING


