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Reduction of Blocking artifacts in Compressed Medical Images

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Abstract. Medical images require large amounts of memory. This calls for image compression (block-based DCT compression) to reduce significantly the amount of data required to represent an image. One of the major drawbacks of the block-based DCT compression methods is that it may result in visible artifacts at block boundaries due to coarse quantization of the coefficients. This paper proposes a new adaptive post-filtering algorithm to remove coding artifacts in block-based DCT compressed medical images. The blocking artifact in the smooth and non-smooth regions are removed by modifying a few DCT coefficients while an edge preserving smoothing filter is applied to the intermediate region. Experimental results illustrating the performance of proposed method on the basis of PSNR, MSSIM, and SF indices are presented and evaluated. Compared with other methods, the proposed one achieves better detail preservation and artifact removal performance with lower computational complexity.

Keywords: Image Compress, DCT.

1. Introduction

Over the past several years, many techniques have been applied to reduce the blocking artifacts in block DCT coded images. Two approaches are generally adopted for the same. In the first approach, the reduction of blocking artifacts is carried out at the encoding side but the methods based on this approach do not conform to the existing standards such as JPEG [1] and MPEG [2]. In the second approach, the reconstructed image is post processed aimed to improve its visual quality without any modification in the encoding or decoding mechanisms, thereby making it compatible with JPEG [1] and MPEG [2] coding standards. Because of this advantage, most of the recently proposed algorithms follow the second approach. Post-processing of the decoded image may be carried out in spatial domain or in frequency domain. Reeve and Lim [3] applied a linear low-pass filter to the block boundaries. Low-pass filtering smoothens out the high-frequency components near the boundaries of DCT blocks. However, low-pass filtering results in blurring around edges of the reconstructed images. A new index to measure the blocking effects namely the mean squared difference of slope (MSDS) has been proposed in the literature [4-6]. It is shown that the expected value of the MSDS increases after quantizing the DCT coefficients. Liu et al. proposed a DCT domain method for blind measurement of blocking artifacts, by modeling the artifacts as 2-D step functions in shifted blocks [7]. Luo and Ward [8] and Singh et al. [9-10] developed techniques, which preserved the edge information. These techniques are based on reducing the blocking artifacts in the smooth regions of the image. 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.

2. Proposed Filtering Method

An attempt has been made in the present research work to further improve the approach presented by Singh et al. [9] by adding the concept of mode detection and filtering algorithm. A low computational deblocking filter with three modes (smooth mode, intermediate mode, non-smooth mode) for low frequency, mid-frequency and high-frequency is proposed. The proposed filter removes the blocking artifact preserving the image detail with minimum loss of image content. The computational load is also reduced because only shifting rather than division is applied. In the proposed technique, the mode of filtering to be used depends upon the region to be filtered, e.g. smooth, non-smooth or intermediate. In order to see whether the region is smooth, non-smooth or complex, the activity across the block boundary is measured by taking eight pixels into account, four on either side of the block boundary. After applying filters on the block boundaries, the blocking artifact is removed without over-smoothing the image details. The objective and subjective qualities are both improved and the computational complexity of proposed deblocking filter is much lower than the deblocking filter of Singh et al. [9].

3. Blocking Artifacts Reduction

In order to reduce the blocking artifacts between two horizontally adjacent blocks, the variation in pixel values across the block boundary called block boundary activity (BBA) denoted by $A(p)$ is measured as under:

$$A(p) = \sum_{k=1}^{7} \emptyset(p_k - p_{k+1}) \quad (1)$$

where p_k indicates k_{th} pixel value as shown in Fig. 1.

$$\emptyset(\Delta p) = \begin{cases} 0, & |\Delta p| \leq S \\ 1, & otherwise \end{cases} \quad (2)$$

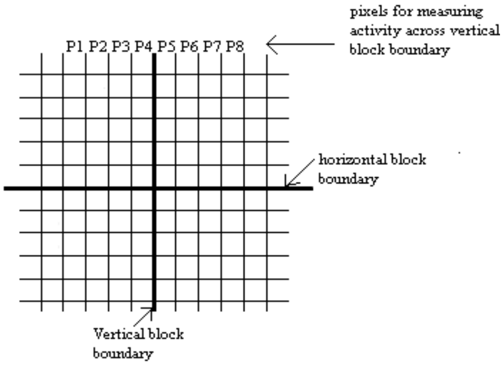


Fig. 1 Pixel contribution for measuring horizontal activity

where Δp indicates the difference in pixel value. Four pixel values on either side of the block boundary as shown in Fig.1 are taken into account to measure the activity across the block boundary. Thus, hence total eight pixel values are used to measure the activity across block boundary.

As more pixel values are used to find the activity *A(p)*, thus it leads to more accurate measurement of blocking artifacts. If the activity across the block boundary is low, this indicates a smooth region; whereas the high activity indicates the region with detailed features (non- smooth). Also if the activity lies between two values, i.e. low and high, the region is termed as intermediate region.

3.1 Smooth region mode

If the two neighboring blocks, have similar frequency properties and the 8×8 pixel area around the block boundary does not have high frequency; the later area is considered to be of smooth nature as proposed by Singh et al. [9]. The block '*b*' can be considered to be of smooth nature if it satisfies $A(p) < T_1$. In order to reduce the blocking artifacts in smooth regions, the offset at the block boundary is measured as given below:

$$\text{Offset} = |(M + L) - (N + O)| \quad (3)$$

*M, L, N, and O a*re the pixel values across the boundary region as shown in Fig.2.

For the region to be of smooth nature:

$$\text{Offset} < 2Q \quad (4)$$

Here '*Q*' is the quality parameter of JPEG and is used to control the bit-rate of the encoded bitstream. If the sum of pixel values M and L is greater than sum of pixel values N and O.

$If\ (M + L) > (N + O).$

The pixel values K, L, and M are modified as:

$$k = K\text{-offset}/8;$$
$$l = L\text{-offset}/6;$$
$$m = M\text{-offset}/4;$$

The pixel values N, O, and P on the other side of block boundary as shown in Fig. 2 are modified as:

$$n = N\text{+offset}/4;$$
$$o = O\text{+offset}/6;$$
$$p = P\text{+offset}/8;$$

3.2 Non-Smooth region mode

If the nature of frequencies of the two neighboring 8×8 blocks differs from each other; the regions are termed as non-smooth regions. The block '*b*' can be considered to be of non-smooth nature if it satisfies $A(p) > T_2$. if the sum of pixel values M and L is greater than sum of pixel values N and O.

$$If\ (M + L) > (N + O).$$

The pixel values L and M are modified as:

$$l = L\text{-offset}/6;$$
$$m = M\text{-offset}/4;$$

The pixel values N and O on the other side of block boundary as shown in Fig.2 are modified as:

$$n = N\text{+offset}/4;$$
$$o = O\text{+offset}/6;$$

3.3 Intermediate region mode

If the nature of frequencies of the two neighboring 8×8 blocks lies between smooth and non-smooth region, the region is termed as intermediate region. The block '*b*' can be considered to be of intermediate nature if it satisfies $T_1 < A(p) < T_2$. Experiments showed that settings S, T_1, T_2 to 2, 1, and 4 respectively would give a good distinction between these modes. Also if the offset is more than $2Q$ in the smooth region or more than 'Q' in the non-smooth region, the intermediate mode filtering is suggested.

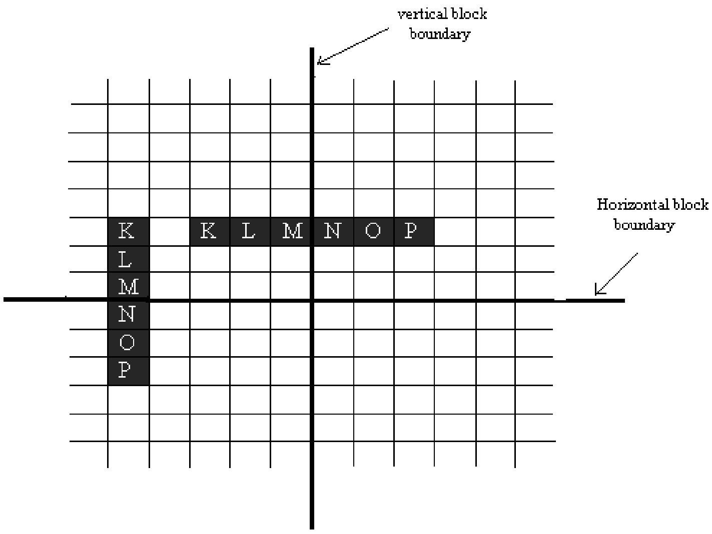


Fig.2 Pixels of the filtering for smooth and non-smooth region

The region is termed as intermediate region, if any one of the following condition is satisfied

$$T_1 < A(p) < T_2 \quad (5)$$
$$A(p) < T_1 \ \&\ \text{Offset} > 2Q \quad (6)$$
$$A(p) > T_2 \ \&\ \text{Offset} > Q \quad (7)$$

The filtering in the intermediate region is not as strong as in case of smooth region but is a balance between the strong filtering in smooth region with the weak filtering in a non-smooth region. A 3×3 smoothing low pass filter is used in the intermediate region to filter the pixels *M* and *N* on either side of the block boundary as shown in Fig.2. Only the pixels near the block boundary are selected in the filtering window. Applying this low pass filter on either side of block boundary reduces the blocking effect with minimal loss of image content.

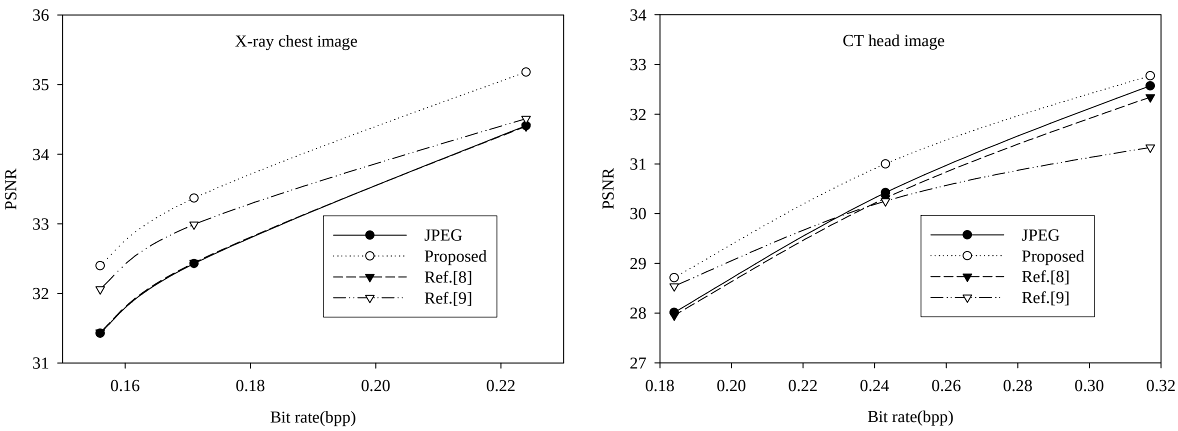
4. Results and Discussion

In order to evaluate the performance of the proposed algorithm, it has been applied to a variety of JPEG compressed images and the results are compared with post-processing technique in DCT domain proposed by [8-9]. The experiment is conducted on three test images namely X-ray chest, CT head and US liver image as shown in Figs. 3(a-c). encoded by JPEG standard to demonstrate the performance of these techniques for various bit rates. The objective quality of the decompressed image is evaluated using the peak signal to noise ratio (PSNR), mean structural similarity index (MSSIM) and similarity factor (SF) indices.

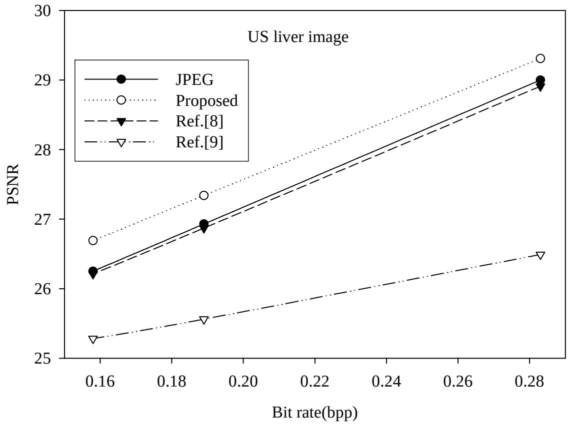
(a) (b) (c)

Fig.3 Test images (a) US liver image, (b) CT head, and (c). X-ray chest.

Figs.4 (a-c) present's experimental results of PSNR obtained by applying the proposed algorithm in comparison with the existing algorithms by Luo and Ward [8], Singh et al. [9]. Figs. 4(a-c) presents that the proposed technique gives best PSNR values as compared to all other methods for all images compressed at different bit rates. Results indicate that the proposed method outperforms all other methods proposed by Luo and Ward [8], Singh et al. [9] in terms of PSNR. It is well known that PSNR is not always a good measure to reflect the subjective image quality. Wang et al. [11] proposed that SSIM indices measure the structural similarity between two image signals. If two images are identical, MSSIM is equal to 1. As shown in Figs.5 (a-c) the reduction in MSSIM index is observed for the post-processing technique proposed by Luo and Ward [8]. This indicates that this method is not retaining the structural similarity as of the original image. Figs.5 (a-c) demonstrates that the proposed method has the highest MSSIM value in comparison with other methods [8-9]. Figs. 5 (a-c) indicate that the difference in MSSIM values for each method is small and thus difficult to recognize. A SF (Similarity Factor) is proposed to evaluate the similarity of two MSSIM. For a test image with a positive SF, the perception quality is more similar to original image than JPEG signal. In comparison, a testing image with a negative SF is considered more degraded. Figs.6 (a-c) exhibits the SF comparison for different post-processing techniques applied to different JPEG compressed images. The proposed method produces a larger SF value for all the three images as compared to methods by Luo and Ward [8], Singh et al. [9]. The proposed method thus reduces the artifact to great extent while preserving the image information, which is important from human observer's point of view.

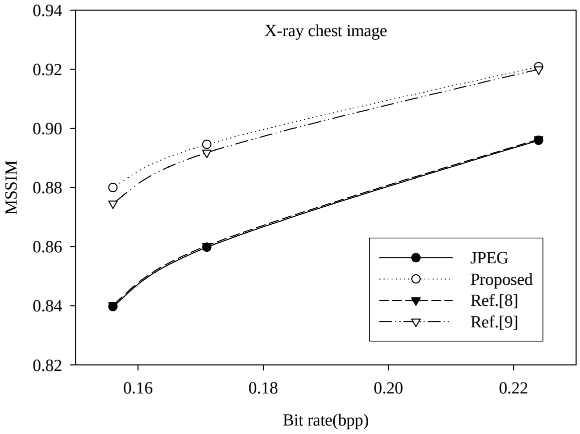


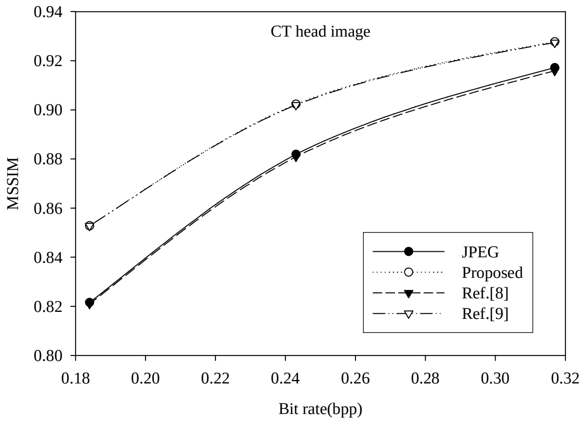
(a) (b)



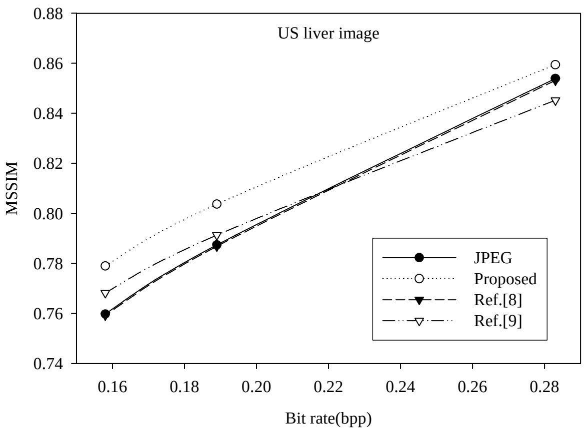
(c)

Fig.4. PSNR results of the proposed algorithm in comparison with the existing techniques for images (a) X-ray chest, (b) CT head, and (c) US liver image.





(a) (b)



(c)

Fig.5. MSSIM results of the proposed algorithm in comparison with the existing techniques for images (a) X-ray chest, (b) CT head, and (c) US liver image.

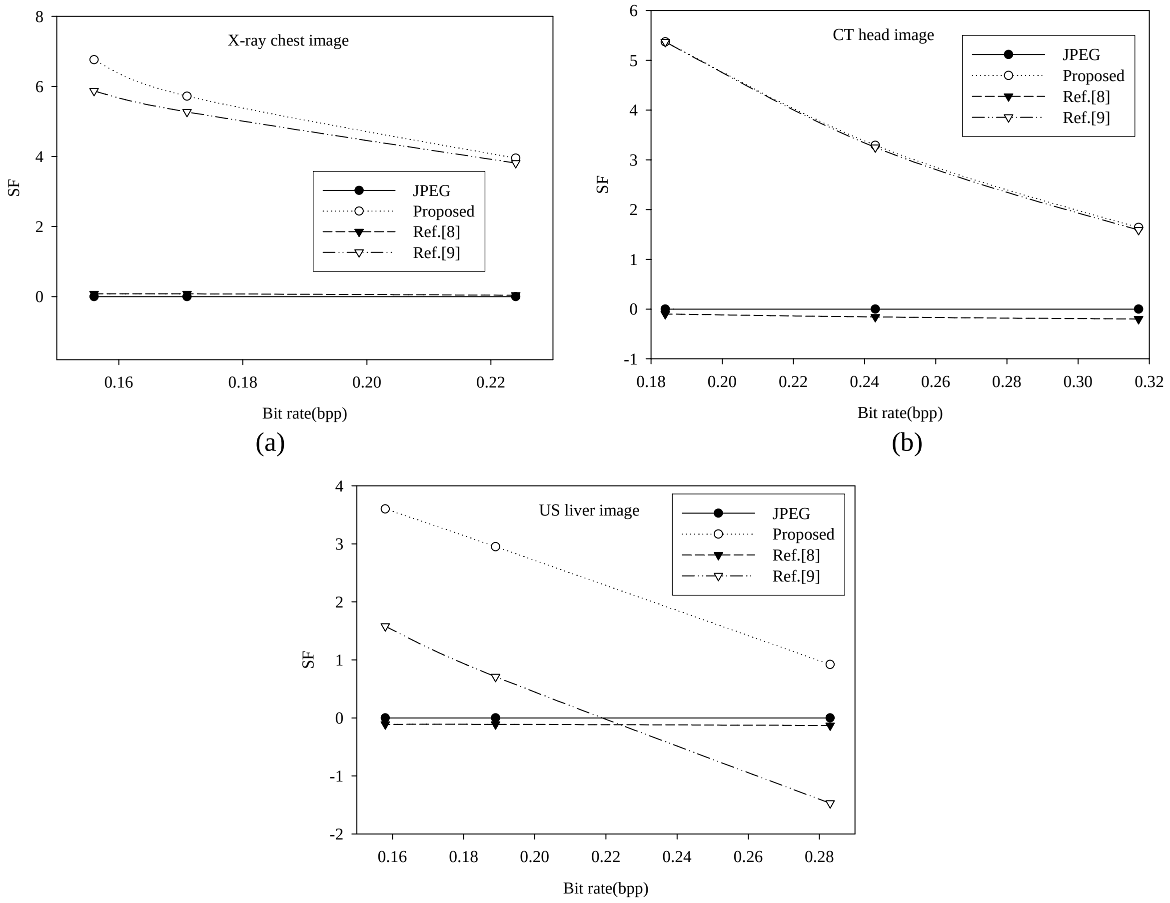


Fig.6. SF results of the proposed algorithm in comparison with the existing techniques for images (a) X-ray chest, (b) CT head, and (c) US liver image.

5. CONCLUSION

In this paper, a new adaptive post-filtering algorithm to remove coding artifacts is proposed. The proposed method detects all possible regions of artifacts and adapts the filtering strength to the detected artifact level. Thus, the time and the computational load of the deblocking algorithm is reduced compared to other deblocking methods. The boundary regions between blocks are identified as smooth, non-smooth and intermediate regions. To demonstrate the performance of the proposed algorithm, PSNR, SSIM index based on HVS perception and SF indices have been used .It is found that there is a significant improvement in the perceptual quality of the JPEG compressed images after removal of blocking artifact by the proposed method..

6. References

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