Blocking Artifact Reduction in Block-Coded Image Using Interpolation and SAF Based on Edge Map

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Abstract: In this paper, we present a new blocking artifact reduction algorithm using interpolation and signal adaptive filter (SAF) based on the edge map. Generally, block-based coding, such as JPEG and MPEG, is the most popular image compression method. However, for high compression it produces noticeable blocking and ringing artifacts in the decoded image. In proposed method, all the block is classified into low and high frequency blocks in block classification procedure. And edge map is obtained by using Sobel operator on decoded image. And according to the block property we applied blocking artifacts reduction algorithm. Namely, four neighbor low frequency block is participated in interpolation based on edge map. And ringing artifacts is removed by applying a signal adaptive filter around the edge using edge map in high frequency block. The computer simulation results confirmed a better performance by the proposed method in both the subjective and objective image qualities.

1. Introduction

Image coding technique based on the block discrete cosine transform (BDCT) are the most popular and have found many applications. Especially, BDCT is used as both still image and moving image coding standards, such as JPEG, H.261, H.263, and MPEG. But the main drawback of the BDCT is the blocking and ringing artifacts. These are the main phenomena caused by block-based coding algorithms.

The blocking artifact consists of the grid noise, staircase noise, and corner outlier. Grid noise appears as a slight change of image intensity along a block boundary in a monotone area. Staircase noise represents the discontinuation of a continuous edge located among blocks. A corner outlier is visible at the corner point of a block, where the corner point is either much larger or much smaller than the neighboring pixels. Plus, improper truncations of high frequency components introduce a pseudo-edge called the ringing artifact.

A spatial LPF is widely used to remove the blocking artifact. Ramamurthi *et al.* [2] classify an image into monotone and edge blocks. Then a 2-D LPF is applied to remove any grid noise in the monotone block and a 1-D LPF is applied to remove the staircase noise in the edge block parallel to the edge block, respectively. However, the classifier used in this algorithm is inaccurate, therefore, the edge block can be blurred if it is classified as a monotone block.

The algorithm proposed by Kim *et al.* [3] classifies an image into smooth region and default modes using the pixel difference in the block boundary. A 1-D LPF is applied to the smooth region mode, then, according to the frequency components in the block boundary, an LPF is applied to the default mode. Although this algorithm can conserve the complex region, it does not eliminate the blocking artifact in the edge region.

Park *et al.* [4] proposed an algorithm using an SAF based on global, local, and contour edge maps obtained using a sobel operator plus the mean and variance of the pixel gradient in the block. A 2-D SAF is applied to all the blocks based on the global and local edge maps, whereas a 1-D LPF is applied along the edge using the contour edge map. The corner outlier is replaced with the mean value of the weighted corner-point pixels. This algorithm produces a better image quality than the algorithm proposed by Ramamurthi *et al.* [2] and works well in removing grid noise but not good at removing in staircase noise.

In this paper, A novel blocking artifact reduction algorithm using a interpolation and SAF based on the edge map. First of all, all the blocks are classified into low or high frequency block and global edge map is obtained by using Sobel operator. Four neighbor low frequency block is participated in interpolation based on edge map. And a 2-D 3-tab SAF is applied to the edge block to remove the ringing artifact. When interpolation and an SAF is applied to the four neighbor low frequency block and edge block, an edge map is used to conserve the characteristic of the edge.

The proposed algorithm can produce a good quality representation of an image from both an objective and subjective viewpoint. To test the proposed algorithm, experiments were performed on images coded using baseline JPEG[1]. The experimental results confirmed that the proposed algorithm is superior to the conventional algorithm due to the suitable interpolation and signal adaptive filter.

The rest of this paper is organized as follows: Section 2 describes the proposed blocking artifacts reduction algorithm in JPEG decompressed images in detail. Computer simulations was performed to verify the performance of the proposed algorithm, whose results are presented in Section 3. finally, Section 4 briefly discusses the conclusions and further works.

2. The Proposed Blocking Artifacts Reduction Algorithm

Blocking artifact reduction algorithm is proposed using interpolation and signal adaptive filter based on edge map. Block classification is performed. In this procedure, all the blocks is classified into low or high frequency block. And edge map is obtained by Sobel operator. Four neighbor low frequency block is interpolated which is reducing blocking artifacts. An SAF is applied to the high frequency block to remove ringing artifact.

2.1. Block Classification

In order to remove blocking artifacts, first, we have to detect areas that have blocking artifacts. It is clear that blocking artifacts are more visible in the low frequency blocks. In our approach we uses similar to Jianping Hu [5] methods to classify the low frequency and high frequency blocks in the transform domain. A block is marked as low frequency block if

$$C_{DCT}(i,j) * K_{low} = \hat{0} \tag{1}$$

Similarly, a block is marked as high frequency block if

$$C_{DCT}(i,j) * K_{high} \neq \hat{0} \tag{2}$$

Where $C_{DCT}(i,j)$ is the 8×8 block of quantized DCT coefficients of block (i,j). $*$ is the element-by-element multiplication. K_{low}, K_{high} are the test metrices for detection of low frequency block and high frequency block respectively. And $\hat{0}$ is the 8×8 matrix of zeros. After a series of experiments, we choose

$$K_{low} = \begin{bmatrix} 00111111 \\ 01111111 \\ 11111111 \\ 11111111 \\ 11111111 \\ 11111111 \\ 11111111 \\ 11111111 \end{bmatrix} \tag{3}$$

$$K_{high} = \begin{bmatrix} 00011111 \\ 00011111 \\ 00011111 \\ 11111111 \\ 11111111 \\ 11111111 \\ 11111111 \\ 11111111 \end{bmatrix} \tag{4}$$

With these choice, we can classify the blocks into low frequency block or high frequency block effectively in JPEG encoded image at low bit rate.

2.2. Edge Map

Interpolation could over-smoothing the image. So edges in the image should not included for interpolation. There are many gradient operators available for edge detection. Sobel operator is our choice because it is simple and easy to be implemented in digital hardware. For Sobel edge detection, the pixel location (m,n) is declared an edge location if $g_{H1}(m,n)$ and $g_{H2}(m,n)$ is greater than a chosen threshold t, where $g_{H1}(m,n)$ and $g_{H2}(m,n)$ are the outputs of the filters whose impulse functions are the Sobel masks. The Sobel masks H1 and H2 are defined as:

$$H1 = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{4}$$

$$H2 = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \tag{5}$$

The threshold of t is determined by experiments in order to obtain the least mean square error of the post-processed image. Edge map is also used to remove ringing artifacts.

2.3. Reduction of Blocking Artifact

Interpolation is performed to low frequency block. In a large flat area, the difference of DC coefficients from adjacent blocks can cause severe blocking effects which are not limited on the block boundary area. If the four adjacent blocks connected each other are combined into a macro block. Next we apply interpolation according to edge map information.

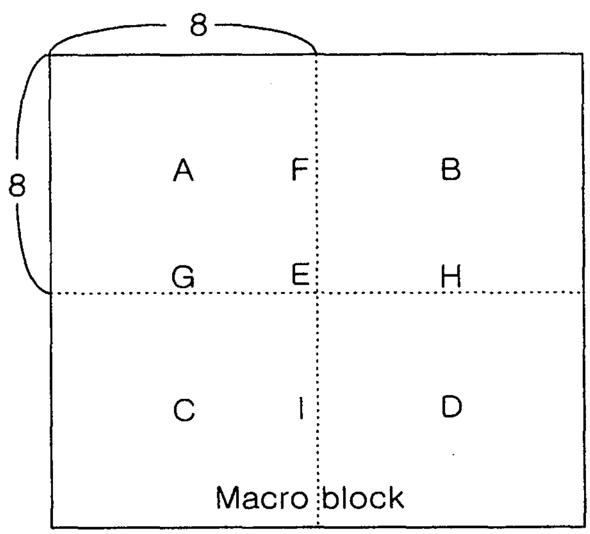

Fig. 1. Structure of macro block and interpolation.

For a specific macro block under concern, we choose a center pixel from each of the four blocks, say at the location (4,4), as our starting point. These center pixels of each block are denoted as A, B, C, and D in Fig.1 respectively. Fig.1 shows the structure macro block and interpolation procedure. And the pixel at location E which has equal distance with A, B, C, and D will be interpolated. The new pixel value at location E is generated by taking average of the surrounding pixels A, B, C, and D. However, if E is the edge pixel, then edge pixel is not participated in interpolation so as to preserve original pixel value. And edge pixel is included among the surrounding pixels A, B, C, and D, then edge pixel is not participated to generate the new pixel E. Our algorithm is a recursive one. On the second stage, we will fill in the pixels at the location F, G, H, and I. This process continues until all the pixels have been filled. With these method, the blocking artifacts have been removed effectively.

2.4. Reduction of Ringing Artifact

To reduce the ringing artifact appearing as a pseudo-edge in the neighborhood of the original edge, a 2-D SAF is performed on the edge blocks.

The SAF applied in the proposed method requires an edge map to preserve an edge. This shows in Fig. 2.

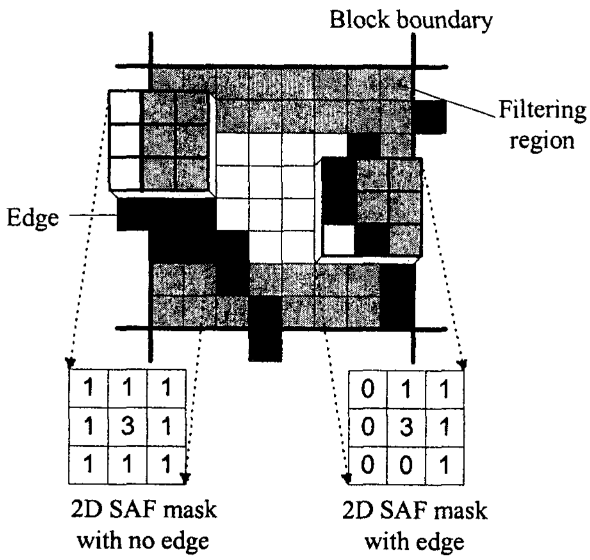

Fig. 2. 2-D 3-tap SAF within edge block.

3. Experimental Results

To demonstrate the performance of the proposed algorithm, computer simulations were carried out to baseline-JPEG[1] decoded images, such as LENA, BOAT, and BANK with a size of 512×512. Although the PSNR is not always a good objective measure of image quality, it is still one of the most popular criteria and, therefore, used as the objective measure in the current experiments. The PSNR results for the post-processed images using JPEG decoding with quantization factors of 2, 3, and 4 are summarized in Table I . The proposed method produced a 0.03~0.2 dB higher PSNR than the conventional methods. Fig. 3 shows a magnified portion of LENA using JPEG decoding with a quantization factor 3 and the post-processed image. The image processed by the proposed method appeared to reduce the blocking artifacts effectively.

4. Conclusions

In this paper, a new blocking artifacts reduction algorithm is proposed to reduce the blocking and ringing artifacts of block-based coded images by using interpolation and signal adaptive filter according to edge map. In the proposed algorithm, we classify all the blocks into low frequency or high frequency block in transform domain and edge map is obtained using the Sobel operator. And four adjacent low frequency blocks connected each other are combined into a macro block is interpolated using the edge information from edge map. And 3-tab SAF is applied to the high frequency block to remove the ringing artifacts. When the SAF is applied to the high frequency block, an edge map is used to conserve the characteristic of the edge. Experimental results show that the proposed algorithm gives better results than the conventional algorithm, from both an objective and subjective viewpoint.

References

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Table I. PSNR of the proposed method and conventional methods on still images.

Test image	Quantization factor	PSNR [dB]			
		JPEG	Ramammurthi	Kim *et. al*	Proposed
LENA	2	32.53	32.58	32.45	32.78
	3	31.31	31.49	31.36	31.58
	4	30.74	31.00	30.76	31.02
BOAT	2	33.26	33.22	33.07	33.31
	3	31.86	32.01	31.77	32.11
	4	30.89	31.13	30.84	31.18
BANK	2	30.63	30.38	30.60	30.54
	3	29.38	29.32	29.38	29.42
	4	28.54	28.58	28.56	28.64

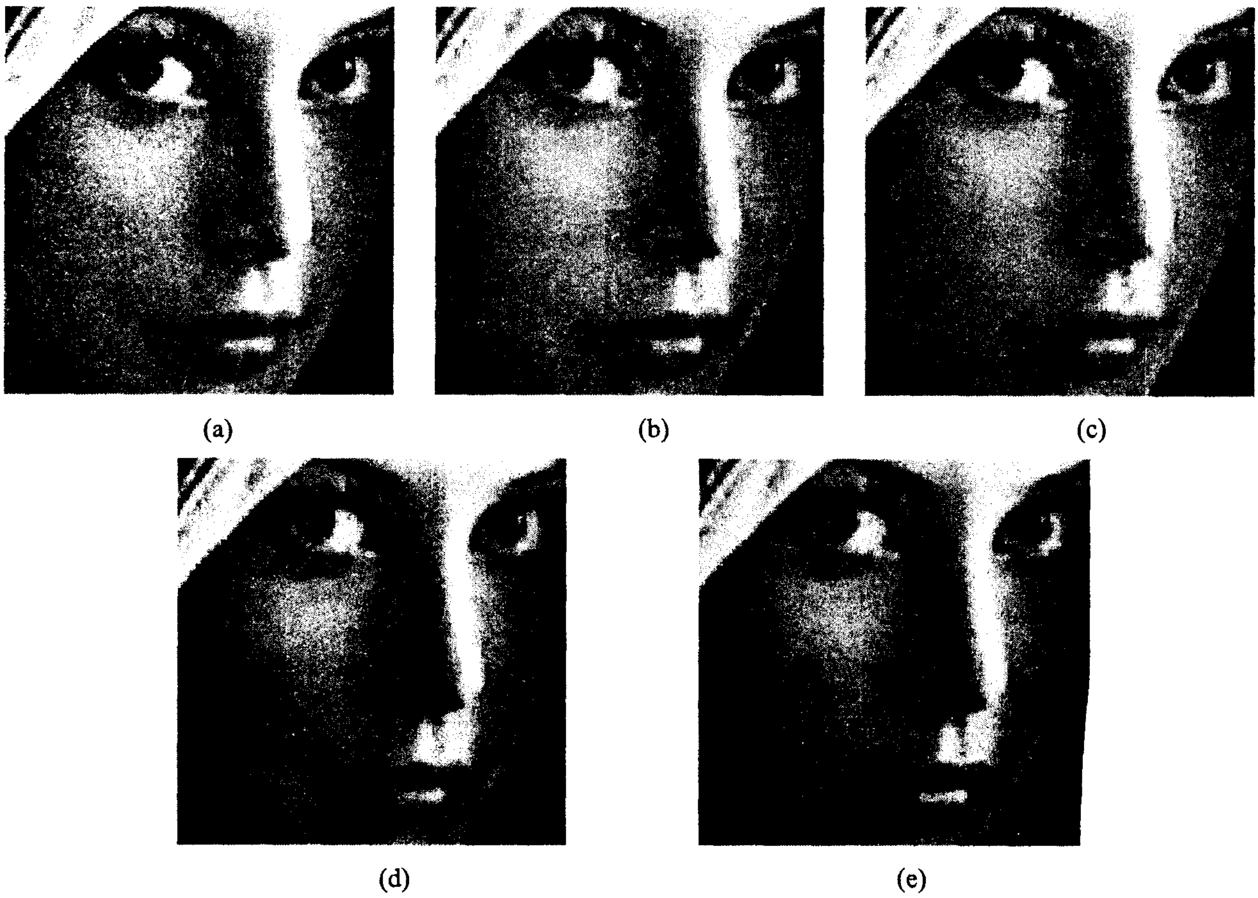

Fig. 3. (a) Original LENA image, (b) JPEG decoded image, (c) Ramammurthi's method, (d) Kim's method, and (e) proposed method.