A new Blocking Artifact Reduction Algorithm Using the Adaptive Filter Based on the Classification of the Block Boundary Area

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Abstract

In this paper, we proposed a new blocking artifact reduction algorithm using an adaptive filter based on the classification of the block boundary area. Generally, the block-based coding such as JPEG, MPEG introduce the blocking artifact and the ringing artifact to the image. The blocking artifact consists of the grid noise, the staircase noise, and the corner outlier. In the proposed method, the staircase noise and the corner outlier are reduced by 1D lowpass filter. Then we classify the block boundaries into two classes based on the gradient of pixel intensity in the boundary region. For each class, adaptive filter is applied so that the grid noise is reduced at the block boundary regions. Next, for the block having the edge component, the ringing artifact is removed by applying the adaptive filter around the edge. Finally the high frequency components are added to only the block boundary in which the natural characteristic is lost by the adaptive filter. The performance of the proposed method is investigated by computer simulation in comparison with the traditional method. In the experimental results, we confirmed the better performance in the subjective and objective image quality.

1. Introduction

Because JPEG, H.261, H.263, and MPEG are the block-based image and video coding standards, the degradation of the image quality may be happened at the inter-block and the intra-block. The blocking artifact and the ringing artifact are two major phenomena caused by these block-based coding algorithms. The blocking artifact is consist of the grid noise, staircase noise, and corner outlier. The grid noise appears as a slight change of the image intensity along the block boundary in the monotone area. The staircase noise represents the discontinuty of continuous edge located among the blocks. The corner outlier is visible at the corner point of the block, in which the corner point is either much larger or much smaller than neighboring pixels. Improper truncation of the high frequency components introduce the pseudo-edge called the ringing artifact.

The spatial LPF (low pass filter) is widely used in eliminating the blocking artifact. Ramamurthi *et al* [2] classify an image into the monotone block and the edge block. 2D LPF is applied to remove the grid noise in the monotone block and 1D LPF is applied to remove the staircase noise in the edge block parallel to the edge block respectively. But the classifier used in this algorithm is not accurate so that the edge block can be blurred if it is classified as the monotone block. Park *et al* [3] proposed the algorithm using SAF (signal adaptive filter) based on the global edge map, the local edge map, and the contour edge map which are obtained by Sobel operator and the mean and variance of the pixel gradient in the block. 2D SAF is applied all the block using the global and local edge map and 1D 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 represent better image quality than the algorithm proposed by Ramamurthi *et al* [2] and works well in eliminating the grid noise but not the staircase noise. The algorithm proposed by Kim *et al* [4] classify the image into the smooth region mode and default mode using the pixel difference in the block boundary. The strongly 1D LPF is applied to the smooth region mode and the weakly LPF according to the frequency components in the block boundary is applied to the default mode. This algorithm can conserve the complex region but don't eliminate the blocking artifact in the edge region.

In this paper, we propose a new blocking artifact reduction algorithm using an adaptive filter based on the classification of the block boundary area. The 1D 3-tab filter is applied in all the block boundary to eliminate the staircase noise and corner outlier. Then the block boundary which represents the blocking artifact is classified into the monotone and smooth edge region. The 1D 5-tab SAF and the 2D 3-tab SAF are applied to respectively the monotone region and the smooth edge region. The 2D 3-tab SAF is applied to the edge block to eliminate the ringing artifact. When the SAF is applied to the block boundary and the edge block, the edge map is used to conserve the characteristic of the edge.

But because the LPF is applied to the block boundary in which the blocking artifact be happened, the high frequency components around the block boundary are improperly eliminated. To obtain more natural image, the high frequency noise is embedded to the filtered block boundary.

The proposed algorithm can represent the image with the good quality in the objective and subjective viewpoint using the adaptive filter based on the classification of the block boundary area and embedding the noise to the filtered block boundary

Experiment is performed to the image coded by the baseline JPEG [1] and MPEG TM5 [6] to test the proposed algorithm. From the experimental result, we confirmed that the proposed algorithm is superior to the conventional algorithm due to the adaptive filter and the noise embedding.

2. The proposed method

In this paper, we propose a blocking artifact reduction algorithm using an adaptive filter based on the classification of the block boundary area. The SAF is applied to all the block boundary to eliminate the staircase noise and the corner outlier. Then the SAF is applied to the edge block and the block boundary having the blocking artifact. The high frequency noise is embedded to the filtered block boundary for the natural image.

2.1. Reduction of the staircase noise and the corner outlier

At all the horizontal and vertical of block boundaries, 1D 3tap pre-filter is performed to reduce the staircase noise and the corner outlier, as shown in Fig. 1.

2.2. Decision of the blocking artifacts and the classification of the block boundary

The existence of the blocking artifact is decided by using the intensity change rate of the 6 pixels within the block boundary as shown in Fig. 2. If the blocking artifacts is decided to exist, the block boundary is classified into one of two region. Firstly, the intensity difference of the two neighboring pixels, D_n is calculated as follows,

$$D_n = |x_{n+1} - x_n| \tag{1}$$

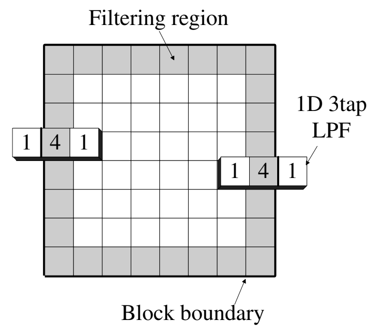

Figure 1: *1D 3 tap filtering at the block boundary.*

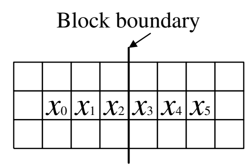

Figure 2: *The 6 pixels for the classification within the block boundary area.*

If D_n is larger than any other intensity difference, the blocking artifact is decided to exist in the block boundary. Among its block boundary, if $D_0 = D_1 = D_3 = D_4 = 0$ and $D_2 > 0$, then it is classified to the monotone area, and if $D_1 > 0$, $D_3 > 0$ and $D_2 > D_1$, $D_2 > D_3$, then it is classified to the smooth edge area.

2.3. Adaptive SAF according to the classification of the block boundary

To reduce the staircase noise which still remains after 1D LPF in section 2.1, SAF is performed to the two classified region. If there is an edge in the filtering mask, the pixels in the location as well as the direction of an edge are not included in this filtering. That is, the weighting values of

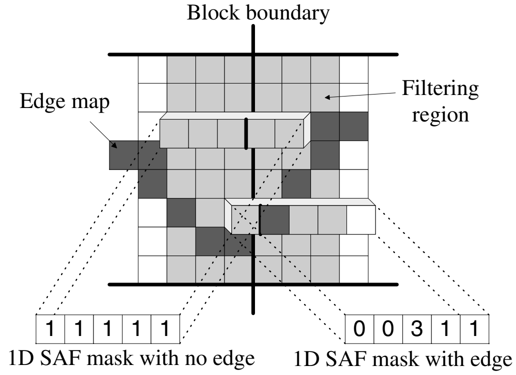

Figure 3: *1D 5 tap SAF within the monotone area.*

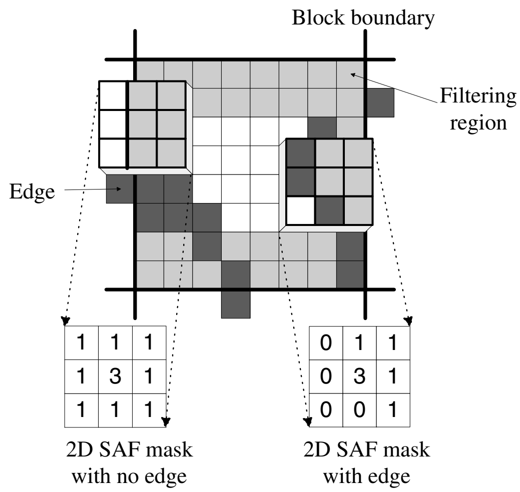

Figure 4: 2D 3tap SAF within the smooth edge area.

the filtering mask are set to zero in that location, as shown in Fig. 3. 1D 5tap SAF is performed to smooth the block boundary within the monotone area and 2D 3tap SAF is performed within the smooth edge area, as shown in Fig. 3 and Fig. 4.

2.4. Reduction of the ringing artifact

To reduce the ringing artifact appeared to be a pseudo-edge in the neighborhood of the original edge, 2D SAF is performed to the edge blocks. Every block is tested whether it contains the edge as follows;

$$\sigma_n \geq \sigma_m \quad (2)$$

where σ_n is the standard deviation of the current block, and σ_m is the mean value of the standard deviation in all blocks. If σ_n is larger than σ_m, the block is decided to be the edge block.

2.5. The edge map according to the image property

SAF applied in the proposed method needs the edge map to preserve an edge. Edge map is made by comparing a threshold value, T_n with an absolute gradient value which is calculated by Sobel operator. T_n is calculated as follows,

$$T_n = T_g - \sigma_n \quad (3)$$

where σ_n is the standard deviation of each block, and T_g is a global threshold value.

$$T_g = \alpha Q_f + \beta \quad (4)$$

where Q_f is the quantization factor, and α and β is experimentally determined.

2.6. Dithering in the filtered block boundary

As the LPF is performed to the block boundary which is discriminated to have the blocking artifact, the high frequency in the neighboring block boundary may be illegally removed and the filtered image appears to be unnatural. In this section, the high frequency component is added in the filtered block boundary for obtaining the more natural image. Each of the intensity differences between a current pixel and 4-neighboring pixels is calculated as follows:

$$t_1 = |x(1,1) - x(0,1)|, \;\; t_2 = |x(1,1) - x(2,1)|$$
$$t_3 = |x(1,1) - x(1,0)|, \;\; t_2 = |x(1,1) - x(1,2)|$$

$$max(t_1, t_2, t_3, t_4) < T_g/6 \quad (5)$$

where $x(1,1)$ is a current pixel, and T_g is a threshold value. If a maximum value among these values is smaller than a threshold value, a current pixel is added to a random noise within 3% limits.

3. Experimental results

In this section, computer simulations have been carried out to demonstrate the performance of the proposed method that reduce the blocking artifact on the JPEG and MPEG decoded images. The proposed method is applied to test images decoded on baseline JPEG [1], such as LENA, BOAT, and BANK of 512×512 size and to test sequences decoded on MPEG TM5 [6], such as FOOTBALL of 352×288 size, using 30 frames. Although the PSNR is not always a good measure of objectively image quality, it is still one of the most popular criteria. And so, it is used for the objective measure in our experiments. Parameters used in Eq. (4), α and β was experimentally determined on 45 and 35 value in respective.

The PSNR results on the post-processed images in JPEG decoding using the quantization factor 2 and 3 is summarized in Table. It shows that the proposed method gives a 0.07∼0.4 dB higher of PSNR than the conventional methods. Fig. 5 shows the magnified portion of LENA in JPEG decoded to the quantization factor 3 and of the post-processed in its image. The image processed by the proposed method appears to reduce the blocking artifact. Table II shows the average PSNR results on which 30 frames of FOOTBALL sequence decoded to 1Mbps and 1.5Mbps on the basis of MPEG TM5 [6] is processed. The proposed method have a little effective in PSNR because of the quantization factor in varying to macro-block unit. But we confirmed that the frame processed by the proposed method appears to reduce the blocking artifact in the large motion portion and ringing artifact in the complex region. In our methods, although an image added noise in the post-processing is on the decrease of PSNR, it appears to be more nature on JPEG as well as MPEG.

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

Test image	Q_f	PSNR [dB]				
		JPEG decoding	Park[3]	Kim[4]	Proposed method	
					before add noise	after add noise
LENA	2	32.53	32.67	32.44	32.91	32.69
	3	31.31	31.68	31.36	31.89	31.69
BOAT	2	33.08	33.19	32.93	33.59	33.39
	3	31.55	31.93	31.56	32.21	32.04
BANK	2	30.52	30.66	30.50	30.73	30.61
	3	29.21	29.54	29.26	29.62	29.52

Table II. PSNR of the proposed method and conventional methods on FOOTBALL sequences.

bit rate	Average PSNR [dB]				
	MPEG decoding	Park[3]	Kim[4]	Proposed method	
				before add noise	after add noise
TM5 1Mbps	28.23	28.27	27.96	28.37	28.33
TM5 1.5Mbps	30.26	30.16	29.35	29.93	29.84

4. Conclusions

We proposed a blocking artifact reduction algorithm using an adaptive filter based on the classification of the block boundary area. The 1D 3-tab filter is applied in all the block boundary to eliminate the staircase noise and corner outlier. Then the block boundary which represents the blocking artifact is classified into the monotone and smooth edge region. The 1D 5-tab SAF and 2D 3-tab SAF is applied to the monotone region and smooth edge region respectively. 2D 3-tab SAF is applied to the edge block to eliminate the ringing artifact. When the SAF is applied to the block boundary and edge block, the edge map is used to conserve the characteristic of the edge. To obtain more natural image high frequency noise is embedded to the filtered block boundary. The proposed algorithm revealed the image with good quality in the objective and subjective viewpoint.

(a)

(b)

(c)

Figure 5: (a) JPEG decoded image,(b) proposed method (before adding noise), and (c) proposed method (after adding noise).

References

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