Post-Processing for Reducing Blocking Artifacts using Adaptive Low Pass Filtering

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Abstract: In this paper, we propose a post-processing method to reduce the blocking artifacts. We perform the post-processing only in the spatial domain so that it is readily applicable to real-time video decoder. Many approaches proposed so far for deblocking deal with only the luminance signal, but here we propose processing the chrominance signals as well since the low bit rate application where the blocking artifacts are most problematic suffers significantly from the color misalignment caused by blocking artifacts occurring to chrominance data as well. The proposed method is composed of low pass filtering in two steps considering the edge direction. The first step is the IIR low pass filtering in the diagonal direction, and the second step is another IIR low pass filtering in horizontal and vertical directions.

1. Introduction

Most recent video compression coding standards such as H.261, H.263, MPEG-1, 2, 4 use the block-based discrete cosine transform (DCT) and quantization to reduce spatial redundancy, the temporal prediction to diminish temporal redundancy, and the variable length coding(VLC) for statistical redundancy reduction. The basic picture types in video compression are the inter-picture if the motion prediction is applied, and the intra-picture if no the temporal prediction is applied. As the degree of compression increases, a coding algorithm employing the block-based transform starts presenting the so called blocking artifacts which show structured discontinuities of pixel values along block boundaries. This is primarily due to independent block-based transform of each block and subsequent coarse quantization of transform coefficients neglecting correlation over adjacent blocks. According to the characteristic of human visual system(HVS), the blocking artifacts are more perceivable in low frequency region than in high frequency region. Therefore, this makes a picture looking very unpleasant. The artifacts differently appear in an intra and an inter picture. The intra picture carries out transform and quantization without temporal prediction, so the reconstructed intra picture typically shows more structured blocking artifacts than the inter picture. But, the inter picture actually has more complex appearance of blocking artifacts due to the temporal prediction.

Many approaches have been proposed to remove the artifacts and they deal with the grey-scale images [1-4] for the most cases, and if applied to color images, they only process the luminance components, therefore leaving the chrominance components unprocessed. However, it is our observation that the chrominance components play also a significant role in making the reconstructed image look blocky, which typically shows color misalignment along the block boundaries. This problem is rather severe in low bit rate applications, and to make it even worse, the compression in chrominance signals is done in a low spatial resolution.

According to the domain of processing, one can think of low pass filtering in spatial [3,4], and in frequency domain [2,4]. Since in transform coding scheme the quantization is typically performed in frequency domain, filtering in the frequency domain is a natural candidate to consider to remove the blocking artifacts. However, post-processing in the frequency domain requires a forward transform (e.g., DCT) and an inverse transform(e.g., IDCT). It means additional complexity in reconstruction. Since we are interested in applying the post-processing in a real-time applications, we propose a post-processing which carries out adaptive IIR low pass filtering twice in the spatial domain. Finally, we extend the algorithm to apply to the chrominance components simultaneously.

2. Proposed Post-processing Method

Low pass filtering is a very simple but an efficient tool to reduce the blocking artifacts in low frequency region. But, it is also easy to over-smooth high frequency components. Without considering edge directions, one can hardly remove the blocking artifacts significantly in a visual sense. So we propose a two-step low pass filtering method that can minimize over-smoothing by being adaptive to edge direction. We further propose applying the proposed method both to the luminance and chrominance components.

2.2 Proposed Post-processing in the Diagonal Directions

First, the adaptive low pass filtering in diagonal direction is performed. The filtering in the horizontal and vertical directions can considerably remove the blocking artifacts.

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However, the filtering in the horizontal and vertical directions alone has a certain limit in removing the blocking artifacts when an image has diagonal edges or when the bit rate gradually decreases. Specially, when one part of a block has edges, this block appears much blocky than the others because the coarse quantization removes signals accounting for edge components. Because of this reason, we propose a selective IIR low pass filter for diagonal direction (45° or 135° direction). This method removes blocking artifacts in the diagonal direction, and compensates for the discontinuity of an edge block. Figure 1 is the region subject to filtering. Each block accomplishes filtering according to the procedure in Figure 2. As a first step, we decide whether the filtering in diagonal direction should be 45° or 135° (Figure 2(a)) using (1).

$$If(CHECK) = \begin{cases} \text{The filtering for } 135^{\circ} \text{ direction, when } CHECK = 1 \\ \text{The filtering for } 45^{\circ} \text{ direction, when } CHECK = 0 \end{cases} \quad (1)$$

$$CHECK: \{abs(A_5 - A_1) + abs(A_1 - D_1) + abs(D_1 - D_5)\} > \{abs(C_5 - C_1) + abs(C_1 - B_1) + abs(B_1 - B_5)\}$$

We sum the gradients among four pixels for 45° or 135° direction, and we compare the sum of these directions. If the gradient sum of 45° direction is smaller than that of 135° direction, we apply the filtering of 45° direction. In this case, the filtering applies to pixels in *BLOCK 1* and *BLOCK 4* like Figure 1. Figure 2(b) shows the filtering procedure in *BLCOK 1* (45° direction). The filtering is from the block boundary pixel to inner pixels of a block according to the diagonal direction. Before each pixel is filtered, checked is the pixel difference between the pixels in each block boundary. Only when the pixel difference is smaller than a given threshold (TH), the pixel is filtered. It is to minimize over-smoothing, and to maintain the continuous characteristic between neighboring pixels. The low pass filter for 45° or 135° direction is given in (2).

$$\begin{cases} A_1 \, filtering: A_1' = [C_3 \;\; A_1 \;\; B_2] \bullet [1 \;\; 2 \;\; 1]^T //4 \\ A_2 \, filtering: A_2' = [C_6 \;\; A_2 \;\; A_3] \bullet [1 \;\; 2 \;\; 1]^T //4 \\ A_3 \, filtering: A_3' = [A_2' \;\; A_3 \;\; B_4] \bullet [1 \;\; 2 \;\; 1]^T //4 \\ A_4 \, filtering: A_4' = [C_8 \;\; A_4 \;\; A_5] \bullet [1 \;\; 2 \;\; 1]^T //4 \\ A_5 \, filtering: A_5' = [A_4' \;\; A_5 \;\; A_6'] \bullet [1 \;\; 2 \;\; 1]^T //4 \\ A_6 \, filtering: A_6' = [A_5 \;\; A_6 \;\; B_7] \bullet [1 \;\; 2 \;\; 1]^T //4 \end{cases} \quad (2)$$

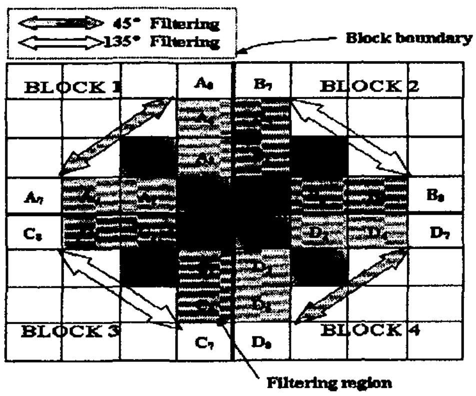
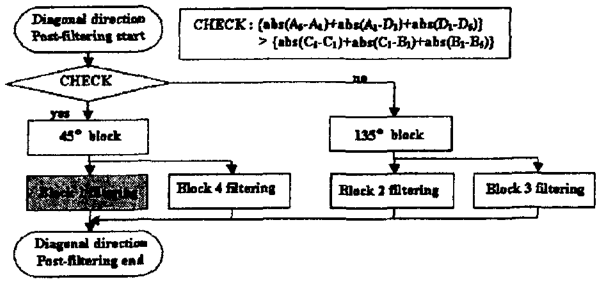
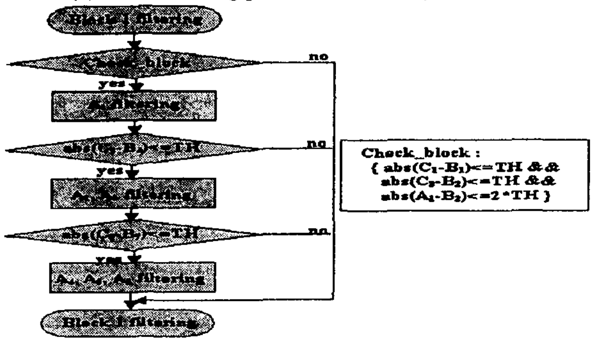


Figure 1. The filtering region and pixel difference in the diagonal direction



(a) The filtering procedure for diagonal direction.



(b)The filtering procedure for *BLOCK1*

Figure 2. IIR low pass filtering procedure in the diagonal direction

2.2 Proposed Post-processing in the Horizontal & Vertical Directions

The filtering in the horizontal and vertical directions can considerably remove the blocking artifacts. Figure 3 shows a region that is subject to filtering to reduce the blocking artifacts for horizontal and vertical direction [4]; each block undergoes filtering according to the procedure in Figure 4.

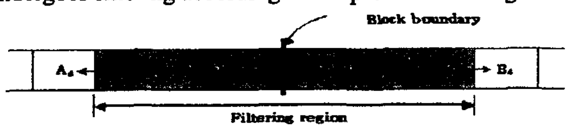


Figure 3. The filtering region and pixel difference in the horizontal direction

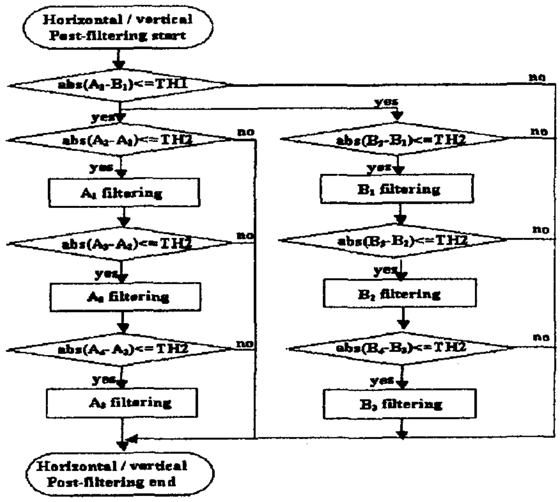


Figure 4. IIR low pass filtering in the horizontal direction

The filtering is from the block boundary pixel to inner pixels of a block. Before each pixel is filtered, checked is the pixel difference between the pixel in a block boundary and the pixel inside the block. Only when the pixel difference is smaller than a given threshold (TH1, TH2), the pixel is filtered. The threshold for pixels inside the block is smaller than that for pixels at a block boundary. is to prevent from over-smoothing, and to maintain the continuous characteristic between neighboring pixels. Figure 4 shows filtering procedure using 1-D 3-tap low pass filter in (3).

$$\begin{cases} A_1\,filtering : A_1' = [A_2 \;\; A_1 \;\; B_1] \bullet [1 \;\; 2 \;\; 1]^T // 4 \\ A_2\,filtering : A_2' = [A_3 \;\; A_2 \;\; A_1'] \bullet [1 \;\; 2 \;\; 1]^T // 4 \\ A_3\,filtering : A_3' = [A_4 \;\; A_3 \;\; A_2'] \bullet [1 \;\; 2 \;\; 1]^T // 4 \end{cases} \quad (3)$$

3. Experiment and Discussion

We have tested the proposed method using the modified H.263 TMN 3.0 codec. To gauge the efficacy of the proposed post-processing technique in reducing blocking artifact, experiment has been conducted with Foreman, Container, and News sequences (100 frame, skip 2). The intra picture carries out transform and quantization without temporal prediction, so the reconstructed intra picture typically shows more structured blocking artifacts than the inter picture. Therfore we need to apply the strong post-processing in intra picture in comparison with inter picture. Consequently, we use a threshod different from the intra picture case according to Qp (Quantization Parameter) value as in (3) :

$$\begin{cases} Horizontal,\ vertical\ direction \begin{cases} TH\,1 = \lfloor 2.5 \times QP \rfloor \\ TH\,2 = \lfloor 1.5 \times QP \rfloor \end{cases} \\ diagonal\ direction : TH = 2 \times QP \end{cases} \quad (3)$$

The inter picuture has less blokiness than intra picuture due to temporal prediction. We use a small threshold value as in (4) :

$$\begin{cases} Horizontal,\ vertical\ direction \begin{cases} TH\,1 = 2 \times QP \\ TH\,2 = 1 \times QP \end{cases} \\ diagonal\ direction : TH = 2 \times QP \end{cases} \quad (4)$$

The comparative results in PSNR for different test sequences are provided in Table 1. In proposed post-processing, the PSNR of luminance is increased by 0.1 ~0.2 dB, the one of chrominance is increased by 0.3 ~ 0.5dB. The over-smoothing of edge can be minimized by precluding edge pixels from low pass filtering by checking the pixel difference with a given threshold, and the adaptive filtering of diagonal direction can remove blocking artifacts in this direction and compensates for the discontinuity of an edge block. We compare the proposed post-processing method with the deblocking edge filter of H.263 in order to estimate more objective performance comparison. (The deblocking edge filter of H.263 is a loop filter. It is performed in the encoder as well as in the decoer side). In Table 1, the proposed post-processing exhibits excellent performance compared to the deblocking edge filter of H.263, providing the best results for the test sequences.

Table 1. Comparison result of the PSNR

(a) Foreman (100 frame, average PSNR)

PSNR(dB)		Qp						
		5	9	13	17	21	25	29
Y	Recon*	36.40	32.77	30.75	29.40	28.43	27.71	27.05
	H.263**	36.45	32.87	30.83	29.40	28.39	27.60	26.98
	proposed	36.47	32.91	30.90	29.53	28.53	27.78	27.13
Cb	Recon*	40.64	38.22	36.92	36.00	35.39	35.1	34.59
	H.263**	40.90	38.56	37.34	36.54	35.92	35.4	34.95
	proposed	40.72	38.49	37.27	36.37	35.74	35.41	34.87
Cr	Recon*	41.16	38.55	37.11	35.93	35.12	34.55	34.03
	H.263**	41.57	38.85	37.5	36.37	35.48	34.95	34.49
	proposed	41.36	38.86	37.46	36.29	35.5	34.89	34.36

(b) News (100 frame, average PSNR)

PSNR(dB)		Qp						
		5	9	13	17	21	25	29
Y	Recon*	37.04	33.13	30.90	29.37	28.20	27.30	26.44
	H.263**	36.88	33.13	30.87	29.30	28.14	27.23	26.39
	proposed	37.21	33.36	31.14	29.56	28.35	27.42	26.49
Cb	Recon*	40.21	37.17	35.35	34.24	33.44	32.45	31.79
	H.263**	40.31	37.48	35.75	34.86	34.09	33.14	32.53
	proposed	40.34	37.43	35.59	34.65	33.98	32.89	32.20
Cr	Recon*	40.78	37.89	36.46	35.58	34.68	34.05	33.72
	H.263**	41.02	38.26	36.96	36.06	35.17	34.63	34.05
	proposed	41.00	38.13	36.77	35.92	35.14	34.52	34.07

(c) Container (100 frame, average PSNR)

PSNR(dB)		Qp						
		5	9	13	17	21	25	29
Y	Recon*	36.71	33.08	30.92	29.29	28.22	27.36	26.68
	H.263**	36.22	32.87	30.7	29.00	28.05	27.15	26.45
	proposed	36.81	33.25	31.13	29.46	28.37	27.43	26.71
Cb	Recon*	41.43	38.87	37.40	36.53	35.87	35.16	34.95
	H.263**	41.40	39.14	37.81	37.14	36.47	35.91	36.00
	proposed	41.53	39.25	37.69	36.96	36.29	35.59	35.49
Cr	Recon*	41.01	38.20	36.82	35.81	34.87	34.18	34.05
	H.263**	41.15	38.32	36.94	36.27	35.46	34.82	34.63
	proposed	41.13	38.39	36.97	36.13	35.28	34.61	34.44

Recon* : reconstructed sequence without post-processing
H.263** : reconstructed sequence using the deblocking edge filter of H.263 in Annex J

Figure 5 is the reconstructed first frame (intra frame) of Foreman sequence with Qp =11. Figure 5(a) is the reconstructed image without any post-processing (no optional mode), Figure 5(b) is the same reconstructed frame obtained with using the H.263 deblocking edge filter, and Figure 5(c) is the same reconstructed frame but improved by the proposed method. The blockiness has been considerably reduced, and the color bleeding over block boundaries now disappears in Figure 5(c) (see the collar area of the person in the figure). Figure 6 is another reconstructed example of the fourth frame (inter frame) of Foreman sequence with Qp=11, skip=2.

(a) reconstructed image without post-processing

(b) reconstructed image with H.263 post-processing

(c) reconstructed image with proposed post-processing

Figure 5. Comparison of reconstructed image
(Foreman sequence, Intra frame, 176 x 144)

(a) reconstructed image without post-processing

(b) reconstructed image with H.263 post-processing

(c) reconstructed image with proposed post-processing

Figure 6. Comparison of reconstructed image
(Foreman sequence, Inter frame, 176 x 144)

Figure 6(a) is the reconstructed image without any post-processing, Figure 5(b) is the same reconstructed frame applied by H.263 deblocking edge filter, and Figure 6(c) is the same reconstructed frame, improved by the proposed method.

4. Conclusion

In this paper, we propose a post-processing method to reduce the blocking artifacts. We perform the post-processing only in the spatial domain so that it is readily applicable to real-time video decoder. Here, we propose processing the chrominance signals as well since the low bit rate application where the blocking artifacts are most problematic, suffers significantly from the color misalignment caused by blocking artifacts occurring to chrominance data as well. The proposed method is composed of simple two steps low pass filtering that can minimize over-smoothing by being adaptive to edge direction. The experimental results obviously show improvement of subjective as well as objective quality.

References

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