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A directional deblocking filter based on intra prediction for H.264/AVC

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Abstract: Although the adaptive deblocking filter of H.264/AVC efficiently reduces blocking artifacts for most images, it is limited in removing the blocking artifacts of the directional edge on the block boundaries. In order to solve this problem, we propose a directional deblocking filter based on intra prediction direction. The proposed algorithm performs directional filtering according to the direction of the intra prediction mode in order to correctly find the block edge while avoiding computational burden. Experimental results show that the proposed algorithm provides subjective improvements at the directional edge and PSNR gain of up to 0.13 dB.

Keywords: deblocking filter, intra prediction, H.264/AVC

Classification: Electron devices, circuits, and systems

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1 Introduction

The adaptive deblocking filter of H.264/AVC [1] efficiently reduces blocking artifacts caused by the coarse quantization of a transformed block and a motion compensated prediction [2]. The filter substantially improved the subjective and objective reconstructed video quality with a simple adaptive algorithm. The deblocking filtering is performed, if the edges are not detected at the block boundaries, in order to preserve sharpness of edge.

Although an adaptive deblocking filter of H.264/AVC operates well for most images, the filter is limited in removing the blocking artifacts of the directional edge on the block boundaries. This is because the algorithm is performed via horizontal and vertical filtering to remove the blocking artifacts without consideration of the directional edge. Therefore, even though the deblocking process is performed, the artifacts along the edge remain.

In order to solve this problem, several directional deblocking filtering algorithms have been proposed [3, 4]. After finding the edge orientation of the block boundaries, the algorithms performed directional filtering along the calculated edge orientation. The algorithms provided subjective quality improvement. However, they utilized complicated pre-calculation methods for each block boundary for both the decoder and encoder in order to find the edge orientation. Since these algorithms find the edge orientation on the blurred image, the calculated direction is also not accurate.

In this paper, we propose a directional deblocking filtering algorithm based on an intra prediction direction in order to avoid pre-calculation for the edge boundaries, as well as accurately finding the edge orientation. The mode of intra prediction can provide correct edge information for 4x4 blocks, and this information can be used directly without additional calculations. The proposed deblocking filter performs directional filtering along the direction of the intra prediction mode.

This paper is organized as follows: section 2 briefly introduces the direction of the 4x4 intra prediction mode, section 3 presents the proposed deblocking filtering algorithm based on the 4x4 intra prediction. In section 4, we show the subjective and objective results for the proposed algorithm and the conclusion is given in section 5.

2 The 4x4 intra prediction

Intra prediction is a newly adopted method for H.264/AVC which reduces spatial redundancy. In intra prediction mode, the current block is predicted via reconstructed neighbor blocks. For the luma samples, H.264 exploits the 4x4, 8x8 and 16x16 intra prediction modes. Directional deblocking filtering, based on intra prediction, can be adopted by a 4x4 intra prediction mode and an 8x8 intra prediction mode. In this section, we briefly introduce a 4x4 intra prediction mode, and the 8x8 intra prediction mode can be extended and described in the same manner as done for the 4x4 intra prediction mode.

The 4x4 intra prediction mode has one DC mode and eight directional modes. Two modes of the eight modes are the horizontal and vertical mode,

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and the remaining six modes (i.e., labeled 3-8) have a slanted direction, e.g. 45°:3, 135°:4, 116.6°:5, 153.4°:6, 63.4°:7, 26.6°:8. The prediction for the 4x4 block current is calculated using the boundary pixels of the previously decoded blocks above and to the left of the current block. Since the pixels along the direction of the local edge have similar values, an accurate prediction can be achieved if the direction of the prediction mode is the same as the edge direction of the block. Therefore, it is understood that the coded intra prediction mode correctly reflects the edge trend of the block.

3 Proposed adaptive deblocking filter

The deblocking filter process for H.264/AVC is applied to all 4x4 block boundaries of a picture. For each block, the vertical boundaries are filtered first, and then horizontal boundaries are filtered. With H.264/AVC, horizontal filtering is performed in vertical boundaries and vertical filtering is performed in horizontal boundaries. However, the proposed algorithm performs directional filtering in vertical and horizontal boundaries in order to remove blocking artifacts along the directional edge.

The proposed algorithm only applies to the intra macroblock mode due to the use of the direction information of intra prediction mode. Therefore, we first identify the macroblock mode of pixels located within the block boundary. If the macroblock mode is the 4x4 intra mode, then the intra prediction based deblocking filter is applied. If not, then the conventional adaptive deblocking filter [2] is processed. The details of filtering direction, artifact detection, and filtering are described in the following paragraphs.

3.1 Filtering direction based on intra prediction

In this subsection, we introduce the deblocking filtering direction based on intra prediction. The 4x4 intra prediction has eight directional modes and a DC mode. Since the DC mode is a non-directional mode and two of the directional modes are horizontal and vertical, these modes can be handled by a conventional deblocking filter. Therefore, we only adopt our algorithm to six other directional modes, i.e., modes 3, 4, 5, 6, 7 and 8.

Figure 1 shows the samples to be filtered according to each intra mode for vertical boundaries. The bold line represents the vertical block boundary to be filtered and the gray dotted line represents the 4x4 block boundaries. There is a block boundary inside two neighboring 4x4 blocks, which have two intra prediction modes. A block is predicted by the left and above samples, therefore, the intra mode of the right block of the vertical boundary can present an edge with a vertical boundary, and an intra mode of a bottom block with a horizontal boundary can present an edge with a horizontal boundary. The filtering process for horizontal boundaries is performed in the same manner of filtering as vertical boundaries. Also, the proposed algorithm can provide a variety mode due to the intra prediction mode as a result of our algorithm and can, therefore, represent a smooth contour of a natural image.

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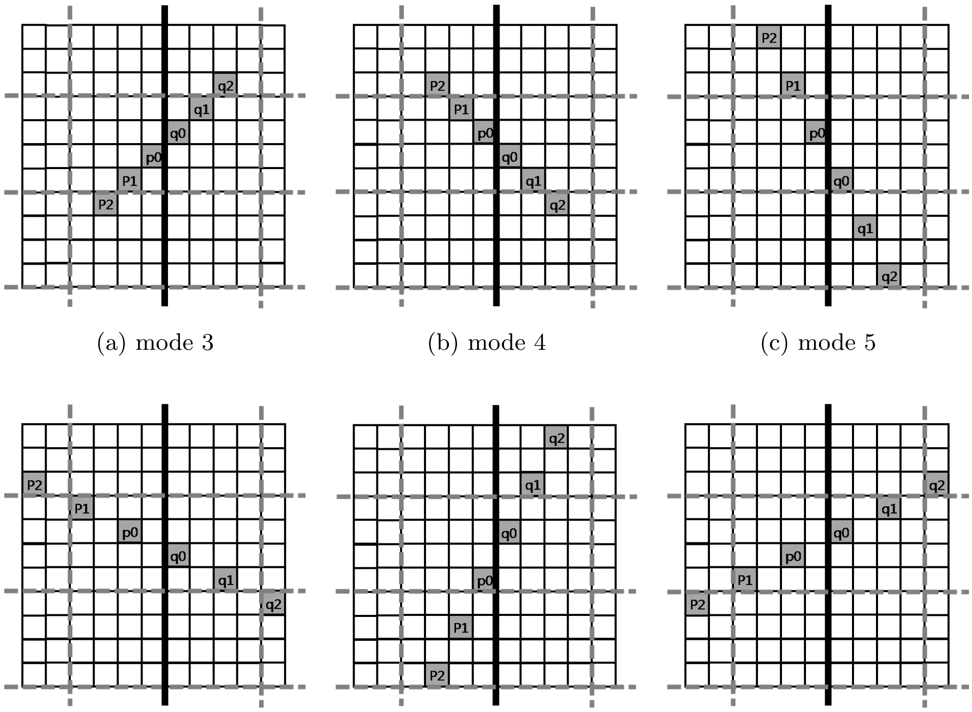

(a) mode 3 (b) mode 4 (c) mode 5

(d) mode 6 (e) mode 7 (f) mode 8

Fig. 1. Filtering direction at 3-8 mode in vertical edge

3.2 Blocking detection

The mode of a 4x4 block can reflect the local edge of a block. However, in a sample level, the edge direction of some samples are not always identical to the edge direction of a block. This is because the intra mode of the block shows only the block's edge trend. Therefore, we need to distinguish between anti-directional texture and blocking artifact along the block edge. If the samples are classified as an anti-directional edge, the samples should be left unfiltered in order to preserve image sharpness. If not, then the samples will be filtered in order to obtain a smooth image along the edge.

In order to separate these two cases, we exploit the block detection method of the adaptive deblocking filter [2]. With an adaptive deblocking filter, if the following three equations are all utilized, then only the filtering along a line of samples takes place.

$$|p_0 - q_0| < \alpha \tag{1}$$

$$|p_1 - p_0| < \beta \tag{2}$$

$$|q_1 - q_0| < \beta \tag{3}$$

α and β have been defined based on empirical test in order to produce visually pleasing results in both the horizontal and vertical filtering cases. However, we need to readjust these thresholds, because the filtering direction is not horizontal or vertical. We re-adjust α and β using α_offset and β_offset in order to avoid modification of syntax. And α_offset and β_offset were calculated based on experimental testing. We obtained better subjective and objective quality where α_offset is -1 and β_offset is 6.

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3.3 Filtering

Filtering is inherited from the adaptive deblocking filter of H.264/AVC. However, we do not consider boundary strength, and the same filter is applied to all intra blocks with mode values of the 3-8 intra prediction modes. If Eq. (1)–(3) are all utilized, $p0$ and $q0$ will be modified as same manner of adaptive deblocking filter [2].

For the adaptive deblocking filter of the H.264/AVC, two spatial activity conditions are added in order to determine the extent of the filtering for the case of the luma samples. Two additional conditions are shown as follows:

$$|p_2 - p_0| < \gamma \tag{4}$$

$$|q_2 - q_0| < \gamma \tag{5}$$

For Eq. (4) and (5), we used the γ value of adaptive deblocking filter of H.264/AVC [2]. If Eq. (4) and (5) are satisfied, then the p_1 and q_1 are modified as same manner of [2].

4 Experimental results

In order to evaluate the performance of the proposed algorithm, the proposed algorithm is compared to the adaptive deblocking filter [2] of the H.264/AVC and Huang's directional post filter [3], which is the same as the previous directional deblocking filter. We implement these algorithms in JM14.1, and several CIF video sequences are used in the experiments. All frames were encoded with Intra type, and 100 frames were coded within each sequence. Therefore, the generated bit-amount of three algorithms was equal.

Table I shows the overall results. The coding efficiency gain of the proposed algorithm is up to 0.13 dB for the "Foreman" and 0.04 dB for the "Hall monitor". Although the proposed algorithm does not achieve a significant objective improvement, the subjective quality is improved. Figure 2 shows the subjective results. Our algorithm provides a better, smoother contour when compared with previous algorithms. Specifically, the proposed algorithm removed corner-outliers, which compensate the stair shaped discontinuities around a directional edge using the adjacent pixels. However, Huang's filter cannot efficiently remove outliers with a low bit rate because this algorithm finds the edge orientation in the blurred image. In Table I, ΔT indicates the percentage of time increased during deblocking processing compared to [2]. For the proposed algorithm, the deblocking processing time on average is only increased by 6%. While the time of Huang's algorithm on average is increased by 47% due to finding edge orientation. Intra 4x4 region in Table I indicates the ratio of the blocks adopted directional deblocking filtering based on intra prediction. In Intra 4x4 region, the proposed algorithm achieves PSNR gain of up to 0.18 dB for "Foreman" and it provides on average 0.09 dB for whole sequence. ΔT is proportional to Intra 4x4 region, because the proposed algorithm adopts conventional filter [2] in non Intra 4x4 region. Even though the Intra 4x4 region is limited, improved edges provide enhancement of overall picture quality since edges represent many features of image.

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Table I. Overall results at different QP

		loop filter [2]		post filter [3]		proposed algorithm		
Sequence	QP	PSNR (dB)	Bit rate (Kbps)	PSNR (dB)	ΔT (%)	PSNR (dB)	ΔT (%)	Intra4x4 region(%)
Foreman	28	37.93	2014.5	37.96	46.50	38.05	9.50	66.31
	32	35.29	1344.5	35.32	46.12	35.42	8.87	56.26
	36	32.91	877.5	32.93	47.16	33.02	7.73	46.14
	40	30.58	598.2	30.60	47.85	30.65	6.48	34.58
Hall monitor	28	38.98	1905.4	38.98	47.64	39.02	5.54	29.69
	32	36.43	1300.5	36.40	47.39	36.45	4.93	26.37
	36	33.70	904.3	36.65	47.82	36.70	4.02	22.68
	40	30.97	635.9	30.93	48.18	30.96	3.65	19.78

(a) loop filter (b) Huang's algorithm (c) proposed algorithm

(d) loop filter (e) Huang's algorithm (f) Proposed algorithm

Fig. 2. Details of the luminance output. The 1st frame of the "Foreman" (a)-(c) and "Hall monitor" (d)-(f) are encoded with QP=40

5 Conclusion

In this paper, we proposed a directional deblocking filter based on intra prediction for a H.264/AVC in order to reduce the blocking artifact at the directional edge of block boundaries. Experimental results show that the proposed algorithm provides a visually pleasing image in directional edge region. The proposed algorithm does not need a computational burden in order to find the edge orientation in intra coding. Also, this algorithm can be implemented without syntax modification.

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