A STUDY ON EDGE ADAPTIVE DEBLOCKING FILTER

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ABSTRACT

Deblocking Filter (DF) is newly introduced into H.264/AVC to remove blocky artifacts. It improves the picture quality and the improved picture is set to the frame buffer for motion compensation. As a result, higher coding efficiency is achieved by DF. However, if the original image has heavily-slanted patterns, DF removes the edges to be kept because it is applied only perpendicularly to the block boundaries. In this paper, we propose Edge Adaptive Deblocking Filter (EADF) which is applied not only for the perpendicular but also for several slanted directions to deal with the problem. Simulation results showed us that EADF was especially effective for the sequence “Foreman” with PSNR gain of 0.04 dB.

Keywords: H.264/AVC, deblocking filter, blocky artifacts, edge adaptation, coding efficiency

1. INTRODUCTION

Video coding standards such as MPEG-2 and H.264/AVC [1] employ block-based orthogonal transform coding combined with motion compensation. Residual signals are transformed, quantized and entropy-coded on a block basis. This coding scheme effectively reduces the spatial and temporal redundancy of the video data. However, the high-frequency component of the image is lost by block-based quantization, hence blocky artifacts occur in the decoded picture. They are easily noticed and deteriorate picture quality especially at low bit-rates. The degraded picture is referred in motion compensation which results in low coding efficiency. In order to reduce blocky artifacts, a filter is applied to the locally-decoded picture. This in-loop filter is called Deblocking Filter (DF).

To achieve higher coding efficiency, modification of DF was proposed [2]. This work reduces the determination processes and the pixels to be filtered. Besides, an improved DF was proposed [3]. The improved method calculates the activity of each block and classifies the blocks. The filter type is switched according to the results of the classification. Although both methods enhanced the performance of DF, the filtering is done perpendicularly across the block boundaries. Therefore, if the original image has clear slanted-edges, DF could remove them to be kept. This paper introduces a solution.

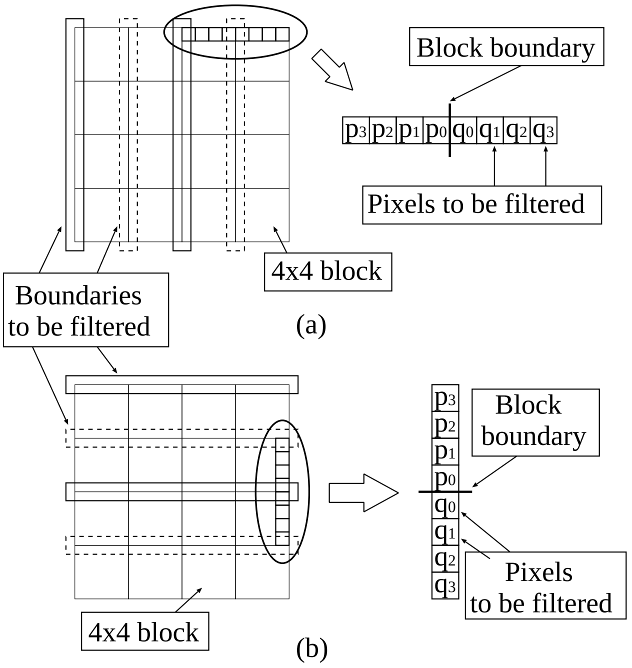

Fig. 1: Positions of block boundaries and pixels to be filtered (a) vertical and (b) horizontal.

This paper is organized as follows. Section 2 describes the conventional DF of H.264/AVC and points out the problem with regard to the limitation of filtering only perpendicularly. Section 3 details the proposed algorithm. Section 4 shows the simulation results. Finally, our conclusion is given in Section 5.

2. CONVENTIONAL DEBLOCKING FILTER

2.1 Process of H.264/AVC DF

In H.264/AVC, DF is applied independently to both luminance and chroma pixels on a Macro Block (MB) basis. Fig. 1 depicts the positions of block boundaries and pixels to be filtered. In the case of luminance MB divided into 8 × 8 blocks, the boundaries in solid-line are filtered. In the case of luminance MB divided into 4 × 4 blocks, those in dashed-line are done as well as solid-line.

The area where blocky artifacts are likely to occur is dependent on the character of an image. Therefore, DF is adaptively performed according to two parameters as fol-

Table 1: Determination method of Bs value.

Conditions	Bs value
“At least one block is intra-coded” AND “The block boundary is on MB boundary.”	4
“At least one block is intra-coded” AND “The block boundary is not on MB boundary.”	3
“Both blocks are inter-coded” AND “At least one block has the transform coefficient(s). ”	2
“Both blocks are inter-coded and don’t have any transform coefficients” AND “The reference frame number or the value of motion vector is different for each other.”	1
“Both blocks are inter-coded and don’t have any transform coefficients” AND “The reference frame number and the value of motion vector are same for each other.”	0

lows:

Boundary strength (Bs) value, and

Absolute value of difference between pixels across block boundaries.

Bs value is determined by the boundary position (MB boundary or block boundary), the block mode (intra or inter), the number of the transform coefficients (0 or more) and the motion information (reference frame number and motion vector value). The determination method of Bs value is shown in Tab. 1.

As shown in Fig. 1, the pixels inside one block are denoted by $p_i(0 \quad i < 4)$ and the ones inside the other block are denoted by $q_j(0 \quad j < 4)$. To be precise, DF is performed under the following conditions:

$$\text{Bs} \quad 0 \tag{1}$$

$$|p_0 \quad q_0| < \quad \text{AND} \ |p_1 \quad p_0| < \quad \text{AND} \ |q_1 \quad q_0| < \tag{2}$$

where and are parameters uniquely determined by Quantization Parameter (QP) value. When Bs $= 4$, strong filtering is performed and six pixels $(p_2, p_1, p_0, q_0, q_1, q_2)$ are changed at a maximum. When Bs < 4, weak filtering is done and two pixels (p_0, q_0) are changed. The strength of DF can be adaptive by Bs value. Besides those parameters, we can control the performance of DF by the parameters of Picture Parameter Set (PPS) in the header as follows: DF is

performed between MB boundaries as well as block boundaries.

done between only MB boundaries.

prohibited.

2.2 Problem of the conventional method

Conventional DF of H.264/AVC is performed only perpendicularly across the block boundaries. In other words, the direction of DF is limited to the perpendicular direction to the block boundaries. The directional character of DF is not considered, although the filtering process is adaptively done in terms of strength and execution. There is a good chance that the filtering could remove the edges to be kept if the original image has slanted patterns as shown in Fig. 2 (a). The loss of edges deteriorates picture quality and results in low coding efficiency.

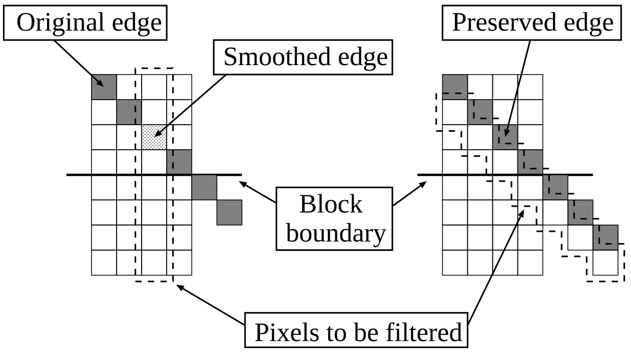

Fig. 2: Deblocking filter examples (a) conventional and (b) proposed.

3. PROPOSED DEBLOCKING FILTER

3.1 Basic idea of the algorithm

To solve the problem described in 2.2, we propose that the direction of filtering is adaptively changed according to the edges which the original image has. As shown in Fig. 2 (b), the filtering is performed at a slant across the block boundaries not only to reduce the blocky artifacts but also to preserve the original edges.

3.2 Edge adaptive deblocking filter

Let us describe the proposed algorithm for the case of a luminance MB divided into 4 × 4 blocks. In what follows, we assume the four edge-directions ($0 \ , 45 \ , 90$ and $135 \ $). Our method proceeds as follows:

Step 1: Divide the decoded MB into 16 blocks of 4×4 and calculate the gradient of each block by

$$\tan\theta = \frac{\displaystyle\sum_{j=1}^{3}\sum_{i=1}^{4}\Big(f(i,j+1) \quad f(i,j)\Big)}{\displaystyle\sum_{j=1}^{4}\sum_{i=1}^{3}\Big(f(i+1,j) \quad f(i,j)\Big)} \tag{3}$$

where $f(i,j)$ means the value of each decoded pixel. The indices i and j $(1 \quad i, j \quad 4)$ are X- and Y-coordinates in each block, respectively. Determine the edge-direction according to $\tan\theta$ by Tab. 2.

Step 2: For each block boundary, select 8-pixel sets to be

Table 2: Definition of edge-direction.

Range of $\tan\theta$	Edge-direction (degree)
$\tan\theta$ 2.414	3 (90)
$2.414 < \tan\theta$ 0.414	4 (135)
$0.414 < \tan\theta$ 0.414	1 (0)
$0.414 < \tan\theta$ 2.414	2 (45)
$2.414 < \tan\theta$	3 (90)

filtered in order according to the edge-direction. Examples are shown in Fig. 3. In the case of (a), 8 pixels lying in the perpendicular direction to the block boundary are selected. Thus, the same filtering is done as H.264/AVC DF. In the case of (b) and (c), the newly proposed filtering is shown. Pixels along the edge-direction are selected and filtered. 17 patterns of pixel selection are prepared in this paper.

Step 3: Determine if the filtering is done or not. Determine the strength of filtering in the case the filtering is done. These processes are judged on the conventional method, i.e. using Eq. (1) and (2). When the filtering is done, go to **Step 4**. Otherwise, go to **Step 5**.

Step 4: The 8-pixel sets selected by **Step 2** are filtered in the same manner as H.264/AVC DF.

Step 5: Determine if the process reaches to the last block boundary. When the last block boundary is filtered, the process of one MB is finished. Otherwise, go back to **Step 2** and proceed to the next block boundary.

The proposed method allows the pixels along the edge-direction to be filtered as well as the pixels lying in the perpendicular direction to the block boundaries. Therefore, the effective filtering can be done by reducing blocky artifacts and preserving the slanted edges the original image has. Needless to say, the proposed method is also applicable to chroma blocks as well as luminance ones.

4. SIMULATION RESULTS

4.1 Experimental conditions

The proposed method was implemented into the KTA software [4] to evaluate its performance and some experiments were conducted for two QCIF (176 × 144) sequences [5]. The encoder configurations were as follows:

KTA software version: 1.8

Profile: High profile

GOP structure: All intra-coded

RD optimization: On

Entropy coding: CABAC

QP values: 37 (fixed)

Intra block sizes: 4 × 4, 8 × 8 and 16 × 16

Number of frames to be encoded: 10 (Foreman is encoded by every two frames.)

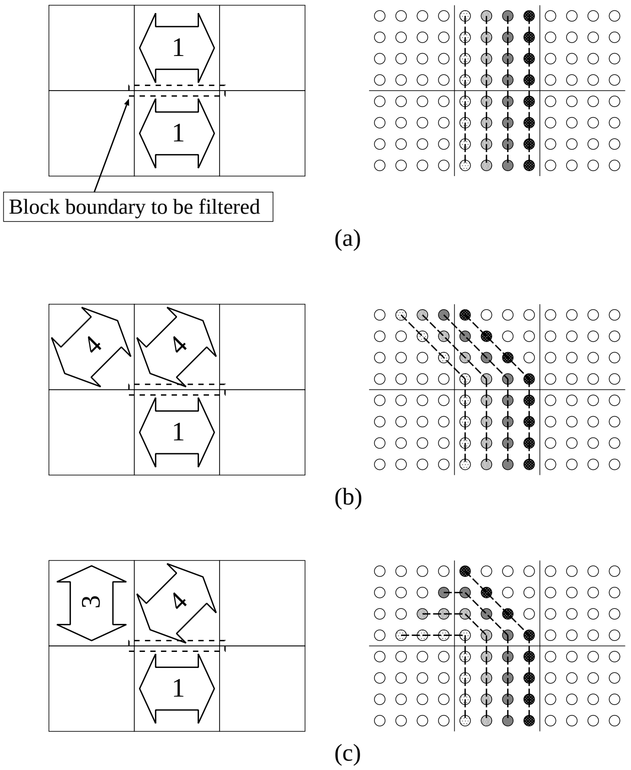

Fig. 3: Examples of 8-pixel sets to be filtered (a) conventional, (b) and (c) proposed. The numbers in the arrows mean edge-direction (cf. Tab. 2).

4.2 Results and analysis

We compared the performances of the conventional method (DF) and the proposed (EADF). Fig. 4 and 5 show frame-by-frame PSNR results. Both sequences were encoded with all intra-coded. Therefore, the generated bit-amount of EADF was equal to that of DF. In the case of Foreman, EADF outperformed DF for all frames. The average gain of PSNR was 0.04 dB. There are long and clear slanted-edges on the background in the initial part of the video. EADF seems to be effective for those slanted patterns. Subjective results are shown in Fig. 6, 7 and 8. There was not a large difference between the subjective results of DF and EADF.

In the case of Mobile, EADF did not outperform DF for almost all frames. This is because the sequence has complicated textures and does not have long and clear slanted-edges as Foreman. Therefore, there is a chance that the filtering along the edges does not work well due to the erroneous edge detection.

5. CONCLUSION

In this paper, we proposed an improved DF method which allows the pixels along the slanted edges to be filtered as well as the pixels in the perpendicular direction to the block boundaries. Simulation results showed that EADF was effective for the sequence that has a lot of slanted edges like Foreman. The average gain of Foreman was 0.04 dB. Future work includes enhancing the accuracy of edge detection and

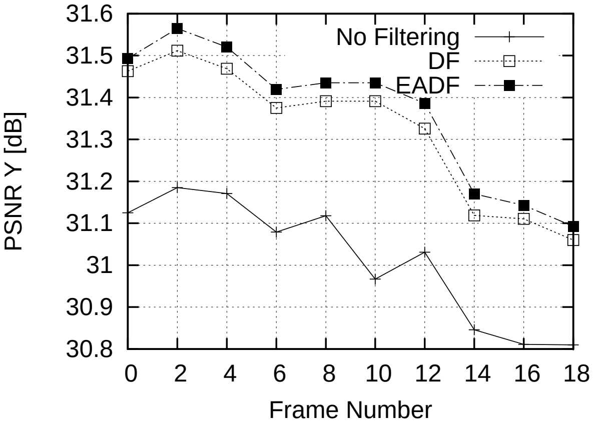

Fig. 4: PSNR performance for Foreman sequence.

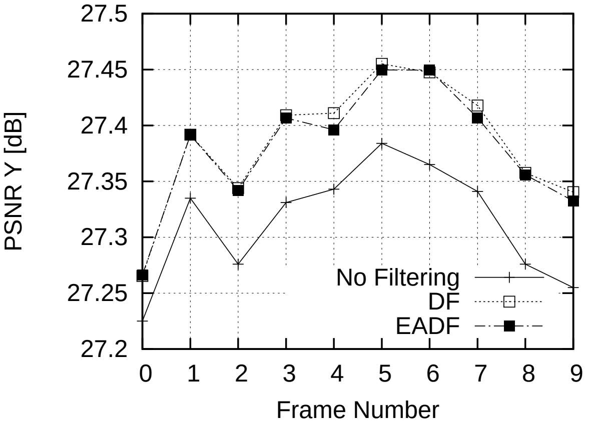

Fig. 5: PSNR performance for Mobile sequence.

conducting the experiments in the case that the number of edge-direction increases.

6. REFERENCES

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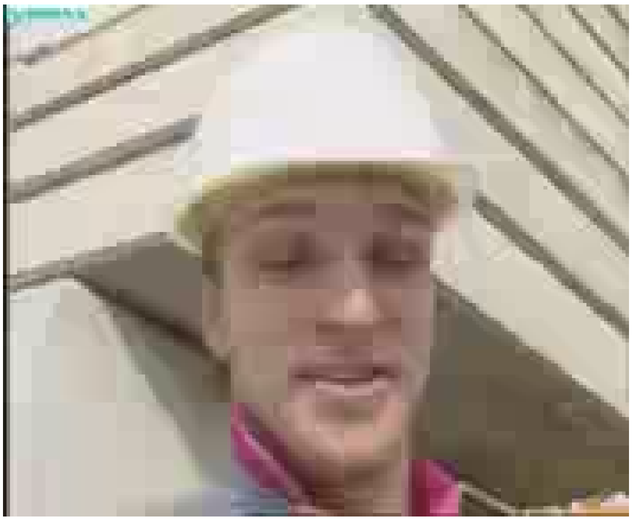

Fig. 6: Subjective result of Foreman for no filtering.

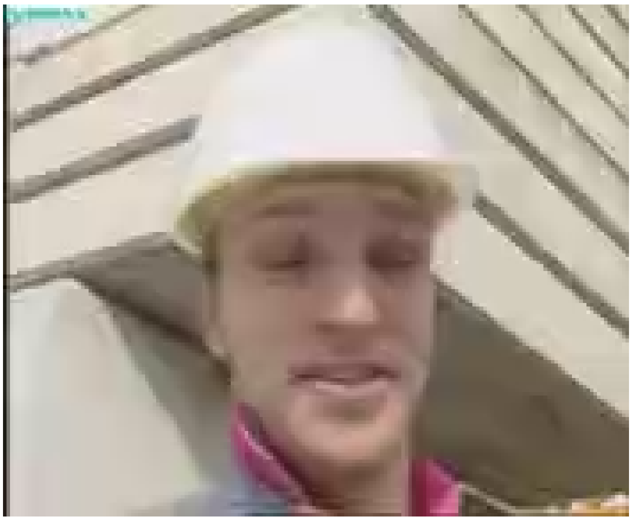

Fig. 7: Subjective result of Foreman for conventional DF.

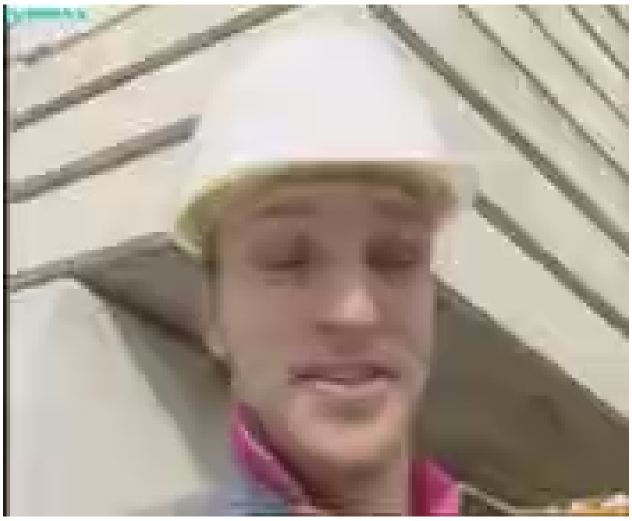

Fig. 8: Subjective result of Foreman for proposed EADF.