IN-LOOP DEBLOCKING FILTER FOR BLOCK-BASED VIDEO CODING

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ABSTRACT

Blocking artifacts are the inherent and inevitable phenomena at low bit rates in the current block-based video coding schemes. This paper proposes a deblocking technique to reduce blocking artifacts and improve visual quality. Different from the post-processing technique adopted in MPEG-4, the proposed technique is directly applied to the reference image for effective motion prediction instead of just for display purpose. In other words, the deblocking filter is introduced into the motion compensation loop in the video coding. Because of the negative effects of deblocking filter such as blurring the details of image, not every block boundary needs to be filtered. The boundaries between two blocks have to be determined whether they should be filtered or not. Therefore, we also propose a decision-making criterion based on the available motion information (vector and mode) in this paper. Experimental results show that the proposed deblocking method can improve image quality both in subjective and objective aspects. It also outperforms the post-processing technique in MPEG-4.

1. INTRODUCTION

Block-based motion compensation and discrete cosine transform (DCT) techniques are proven very successful in various video compression schemes and standards, since they can effectively reduce the temporal and spatial redundancy of video sequences [1]. However, block-based coding techniques, such as that used in MPEG and ITU-T standards, have to suffer from annoying blocking artifacts especially when they are used for low bit rate coding [2]. Two adjacent blocks may lose the original smoothness and continuity at the boundary, due to the fact that most of the DCT coefficients in each block fall into the dead-zone of quantization except for few low frequency coefficients.

Various techniques, such as filtering approach, maximum a posteriori (MAP) probability approach, and iterative approach based on the theory of projections onto convex sets (POCS), have been proposed to improve the reconstructed image quality at low bit rates by alleviating blocking artifacts [1][3]. In MPEG-4 video coding, the overlapped block motion compensation (OBMC) [4] is first introduced as a cross-block prediction method to reduce blocking artifacts. At the same time, a deblocking filter is provided as a post-processing method to improve the visual quality at low bit rates for display purpose only. Although this technique can reduce blocking artifacts at the block boundaries in each displayed frame, since such a process is out of the motion compensation loop, blocking artifacts still exist at the reference images, which may further propagate into the inner regions of blocks in the next frame due to the block-based motion compensation.

This paper tries to move the deblocking filter for post-processing specified in MPEG-4 [5] to the motion compensation loop. In other words, the deblocking process is performed on the reference image instead of the display image. By doing so, the deblocking technique not only removes blocking artifacts at block boundaries but also makes sure that the blocking artifacts would not propagate into the interior of blocks in the frames followed. Consequently, the proposed method can further improve both subjective quality and objective quality of reconstructed images. Since the deblocking process also has a side-effect that may blur the details of an image, the deblocking filter has to be selectively applied to the block boundaries according to the motion vectors and coding modes of these blocks.

The rest of this paper is organized as follows. Section 2 gives a brief overview of the deblocking techniques used in MPEG-4. Section 3 describes the proposed in-loop deblocking technique in detail. The same filter specified in MPEG-4 for post-processing is used here. The experimental results using the proposed technique are presented in Section 4. Finally, Section 5 concludes this paper.

2. DEBLOCKING TECHNIQUES IN MPEG-4

Figure 1 gives a diagram of MPEG-4 video codec [5]. The shape coding is omitted in this diagram. For each INTER coding frame, motion estimation is first performed between the current original frame and the previous original frames or the previous reconstructed reference. The estimated motion vectors are used in block-based motion compensation to generate the current prediction frame. The difference between the current original frame and the prediction frame is processed with 8×8 block discrete cosine transform. The output of the DCT module is quantized and compressed with variable length coding to form the compressed video bitstream. Meanwhile, the dequantized DCT coefficients will go through the inverse discrete cosine transform and are then added into the temporal prediction to form the reconstructed image as the reference for motion estimation and compensation in the next frame.

In order to solve the problem of blocking artifacts, overlapped block motion compensation (OBMC) [4] technique is applied in

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the motion compensation module as proposed in MPEG-4. Instead of only using the motion vector of the current block in traditional motion compensation methods, the OBMC technique utilizes the motion vectors of two neighbor blocks around the current block to smooth boundary pixels in luminance image. In general, pixels located at boundaries are compensated by three motion vectors, the current block and two closest blocks in four neighbors [5]. For example, the pixels at left-upper corner of the current block will use the motion vectors of current block, left neighbor block and upper neighbor block. The final predicted value is the weighted average of three prediction values. Because of the utilization of neighbor motion vectors, the OBMC technique can smooth pixels at boundary in the current block and thereby can reduce blocking artifacts to some extent.

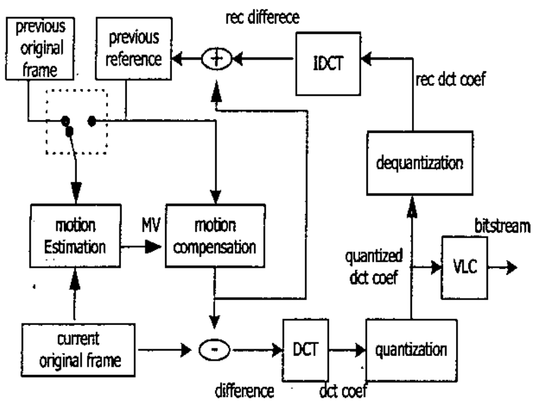

Figure 1: The diagram of MPEG-4 video encoder.

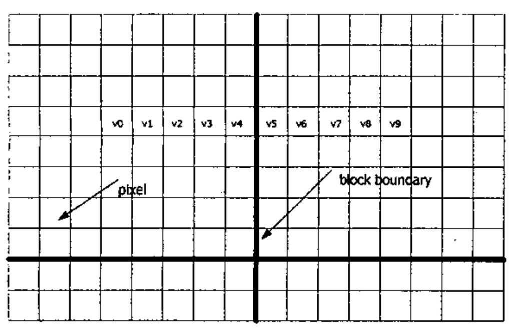

Figure 2: Block boundary and corresponding pixels.

Even though the OBMC technique is adopted for deblocking, the MPEG-4 video codec still can not effectively reduce blocking artifacts at low bit rate coding in some cases. Furthermore, the artifacts can propagate from one frame to another. Therefore, the post-processing technique using deblocking filter is also adopted in MPEG-4 for better visual quality [6]. The deblocking filter used in MPEG-4 is adopted from [2]. In the filtering process, two modes are used depending on the pixel conditions around a boundary. In each mode, proper one-dimensional filtering operations are applied for all block boundaries, first along the horizontal edges followed by the vertical edges. In the first mode, a strong filter is applied inside the block as well as on the block boundary to handle the artifacts propagated from the previous frame. In the second mode, a sophisticated smoothing filter is used to reduce blocking artifacts adaptively based on the frequency information around block boundaries. The following procedure is used to find a very smooth region with blocking artifacts according to which the deblocking mode is decided. As shown in Figure 2, let

$$eq\_cnt = f(v0-v1)+f(v1-v2)+f(v2-v3)+f(v3-v4)+f(v4-v5)$$
$$f(v5-v6)+f(v6-v7)+f(v7-v8)+f(v8-v9)$$
$$where \quad f(x)=1 \; if |x| \leq \mathrm{THR1} \; and \; 0 \; otherwise$$

then if $eq\_cnt \geq \mathrm{THR2}$, the first mode is applied; else the second mode is used in deblocking.

As a postprocessing scheme, this deblocking filtering makes no contribution in reducing the influence of blocking artifacts in motion estimation and the propagation of blocking artifacts in the motion compensation loop.

3. DEBLOCKING TECHNIQUE IN MOTION COMPENSATION LOOP

Based on the post-processing techniques in the MPEG-4 video coding, this paper introduces the deblocking filtering into the motion compensation loop. Figure 3 is the diagram of the MPEG-4 video codec with the proposed deblocking technique.

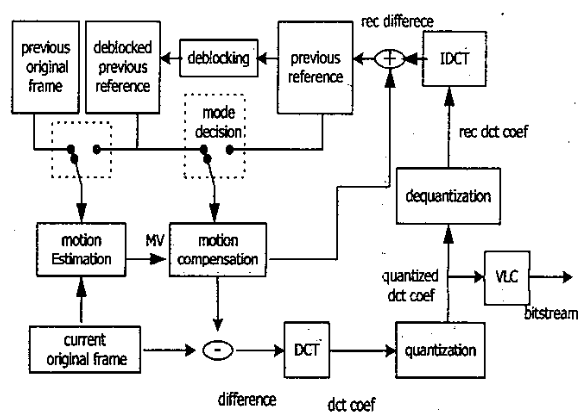

Figure 3: The diagram of MPEG-4 video encoder with the proposed in-loop deblocking technique.

It is well known that the blocking artifacts at either inter blocks or boundaries of blocks will definitely have negative effects on the efficiency of the motion estimation when such reconstructed image is used as prediction reference. Therefore, a natural idea is to apply the deblocking process directly to the reference image rather than only to the display image as in original MPEG-4 encoder. This essentially means to use the deblocking filter in the motion compensation loop. However, if the reference with deblocking filtering is introduced into the motion compensation loop without any additional restrictions, the coding efficiency will degrade since the deblocking process will introduce some errors and drop off some useful high frequency information. Therefore, it is very important for the proposed technique to make a balance between eliminating blocking artifacts and maintaining high coding efficiency. In order to provide a good trade-off between visual quality and coding efficiency, two motion compensation modes are proposed for each macroblock, namely, the default mode and the deblocking mode. In the default mode, the blocks used for motion compensation in reference frame will not go through any deblocking filtering. On the other hand, in the deblocking mode, the blocks used for motion compensation in reference frame are smoothed with deblocking filter. The OBMC scheme is applied in both modes.

A mode-selection mechanism based on the available motion information is further investigated in this paper to select the proper motion compensation mode for each INTER macroblock. Here, pmv is used to represent the motion vector of current macroblock. $pmv.x$ and $pmv.y$ measured by pixel indicate motion magnitudes in the x and y directions, respectively. As mentioned above, the OBMC technique also utilizes the motion vectors from two close neighbor blocks. Therefore, it is observed that the OBMC technique is very effective in deblocking when the motion region locates in the neighboring blocks as shown in Figure 4 with $pmv1$. However, when the motion region is out of the range of neighboring blocks as shown in Figure 4 with $pmv2$, the OBMC technique has little effect on deblocking. In other words, if

$$absolute(pmv.x) + absolute(pmv.y) \geq k,$$

the current macroblock should be coded with the deblocking mode, i.e., the deblocked reference is used in the motion compensation to reduce the effect of blocking artifacts; otherwise the macroblock is coded with the default mode. Here, k is set as 16 which equals to twice of the block size. The current macroblock is also coded with deblocking mode if there are one or more reference macroblocks coded with INTRA mode in the previous frame.

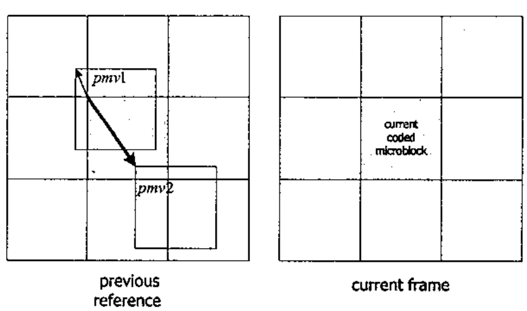

Figure 4 The diagram of motion region

As mentioned before, motion compensation mode of each INTER macroblock is determined by the motion vectors and macroblock INTER/INTRA modes. Since these information can be obtained both in the encoder and the decoder, no additional information is needed to indicate which motion compensation mode is used for each INTER macroblock. It is clear that the proposed method can be easily applied to MPEG-4 video coder.

4. EXPERIMENTAL RESULTS

Experiments have been designed to verify the proposed deblocking technique. The modified MPEG-4 codec is used in the experiments. The advanced prediction mode with 8×8 block motion vectors and the OBMC mode are turned on in the coding configuration. Original frame is used in motion estimation for integer precision, and the deblocked reconstruct reference is used for half-pixel precision. The H.263 quantization method is adopted in the experiments, and TM5 is used for rate control. Four MPEG-4 sequences are tested in the experiments. The encoding frame rate is 10Hz. For all sequences, only the first frame is encoded as I frame, and the others are encoded as P frames. The thresholds in the deblocking filter, THR1 and THR2 defined in the chapter 2, are set to be 2 and 6 respectively. For the QCIF sequences, the range of motion vectors is set to within ±15.5 pixels. For the CIF sequences, the range of motion vectors is set to within ±31.5 pixels.

The coding efficiency of the proposed deblocking technique is compared with that of the original MPEG-4 video codec without any deblocking (ND) and MPEG-4 video codec with post-processing (WD), respectively. The experimental results are shown in Table 1. The proposed method is about 0.2dB higher in PSNR than the original MPEG-4 video codec without deblocking. It is also slightly higher than the MPEG-4 with post-processing.

Table 1 Performance evaluation of the proposed deblocking technique.

Format	Sequence	Bitrate	PSNR_Y[dB]		
			ND	WD	Proposed Method
QCIF	Foreman	48k	30.57	30.69	30.73
QCIF	Carphone	48k	32.91	33.08	33.10
QCIF	Foreman	32k	28.24	28.33	28.42
QCIF	Coastguard	32k	27.36	27.39	27.44
QCIF	Carphone	32k	31.06	31.20	31.25
QCIF	News	24k	30.08	30.24	30.28
QCIF	Carphone	24k	29.80	29.91	29.92
CIF	Foreman	128k	29.96	30.12	30.16
CIF	Carphone	128k	33.69	33.88	33.90

A curve of PSNR versus frame number for Foreman (QCIF) sequence at 32kbits/s is shown in Figure 5. The curve named DD is the result that obtained by using the deblocking reference directly in the motion estimation and compensation without any restriction. Obviously, if the post-processing technique is directly used on the reference image without any constraint, it will cause coding efficiency loss. With the proposed deblocking technique, the MPEG-4 video codec can achieve the best performance among four schemes.

The visual test is performed on the Foreman sequence with QCIF format, shown in Figure 6. Figure 6 (a) and (b) show the

28th and the 31th reconstructed frames of Foreman obtained by MPGE-4 basic codec without deblocking at 32kbit/s respectively. Figure 6 (c) and (d) are the corresponding results obtained by the proposed deblocking technique. Although the OBMC is used in the MPEG-4 video codec, blocking artifacts at low bit rate are still noticeable. The proposed deblocking technique can substantially reduce blocking artifacts of the reconstructed images.

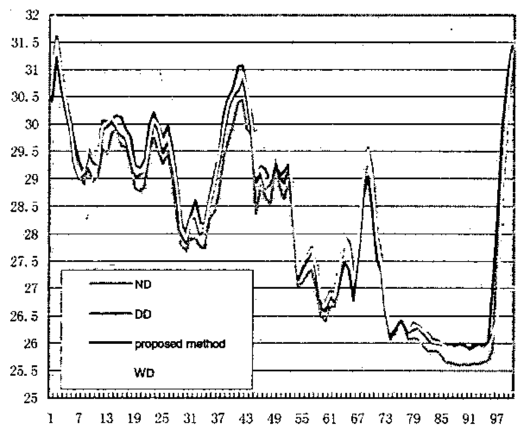

Figure 5 The curves of PSNR versus frame number of Foreman (QCIF)

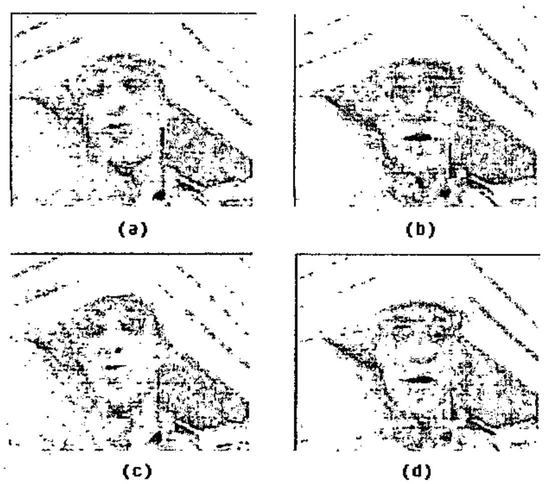

Figure 6 Visual quality comparisons (28th frame and 31st frame in Foreman)

5. CONCLUSIONS

This paper proposes a deblocking technique in motion compensation loop instead of in post-processing stage. A simple criterion based on the available motion information (vectors and modes) determines whether or not the deblocked reference is used. With the proposed deblocking technique, the MPEG-4 video codec can get slightly better performance than that with post-processing technique. If combination of motion information and quantization parameters is used for the criterion, the proposed technique might further improve the coding efficiency and visual quality. This is the next step in our research.

6. REFERENCES

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