OVERLAPPED BLOCK MOTION COMPENSATION FOR FRAME RATE UP CONVERSION

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Abstract: Recently, motion compensated interpolation methods are used to generate new frames in the frame rate up conversion. However, they often yield undesirable blocking artifacts due to inaccurate motion estimation. In order to mitigate these artifacts, we propose a new motion-compensated frame rate up conversion algorithm with overlapped block motion estimation. The new interpolated frame is obtained by overlapped block motion compensation of multiple motion estimation between the current and previous frames. Experimental results show the proposed method produces better perceptual quality and outperforms conventional motion-compensated methods in terms of PSNR.

1 INTRODUCTION

Currently, a number of video frame rates are used in various applications. The typical frame rate ranges from 15 to 60 frames per second. Recently, flat panel displays are widely available and most consumer TV monitors use either LCD or PDP technologies, which display videos with a high frame rate (50 to 120Hz). In order to achieve such high frame rates, the frame rate up conversion (FRUC) is required. FRUC generates additional frames from adjacent frames, thereby improving visual quality with flicker reduction. It can be also applied to low bit rate video coding. If some of frames are skipped at the encoder to archive low bit rate compression, the missing frames can be reconstructed at the decoder using FRUC (Haan, 1999; Dufaux and Moscheni, 1995).

For example, FRUC can be easily implemented using frame repetition (FR) and temporal linear interpolation (TLI), though FR may produce motion jerkiness and TLI produces perceived blurring artifacts. In order to reduce such artifacts, motion compensated FRUC (MC-FRUC) algorithms have been proposed.

Many motioncompensated interpolation (MCI) algorithms with motion estimation (ME) have been proposed for FRUC (Choi et al., 2000; Gao et al., 2008; Haan, 1999; Ha et al., 2004; Ojo and Haan, 1997). These methods use the motion information of two or more adjacent frames and motion vectors (MVs) are used to reconstruct a new frame from the corresponding frames using motion compensated interpolation (MCI). In general, block matching algorithms are employed for motion estimation and compensation between adjacent frames due to the simplicity and easy implementation. However, they often yield undesirable artifacts such as blocking and incompatible block degradation resulted from inaccurate motion information.

To mitigate this problem, we propose a new MC-FRUC with overlapped block motion compensation (OBMC) (Orchard and Sullivan, 1994), which uses multi-estimators and shifted grid. Then, we produced new frames by averaging the overlapped block motion compensation results from the mulitple motion estimations.

2 PROPOSED METHOD

2.1 Motion Estimation and Motion Compensation Interpolation Methods

To obtain motion vectors, we used uni-directional ME (UDME, Figure 1) and bi-directional ME (BDME, Figure 2) methods (Choi et al., 2000).

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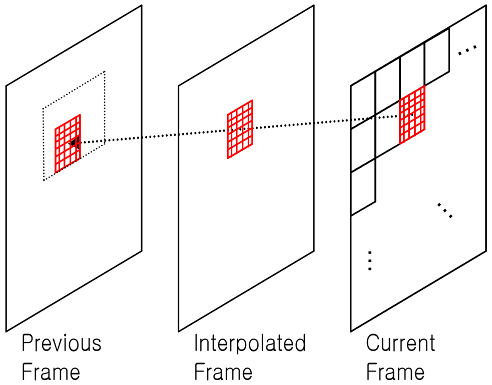

Figure 1: The uni-directional motion estimation (UDME) method.

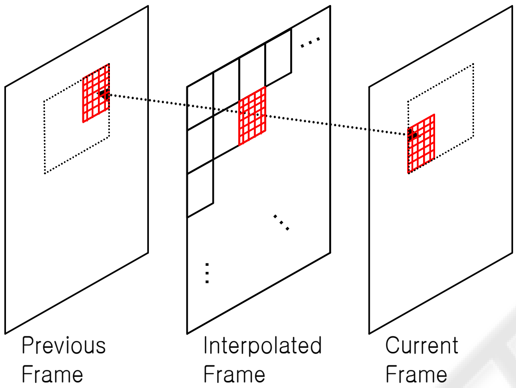

Figure 2: The bi-directional motion estimation (BDME) method.

The proposed method first performs block-based motion estimation for each macro block between the previous and current frames. Let B_j^P be the best matching block in the previous frame for the j-th block of the current frame (B_j^C). The block size is $w \times h$ and the sum of absolute difference (SAD) is used. The new block B_j^I in the interpolated frame is obtained by averaging the two matching blocks of the previous and current frames:

$$B_j^I(x,y) = \frac{1}{2}\left[B_j^C(x-v_x, y-v_y) + B_j^P(x+v_x, y+v_y)\right] \quad (1)$$

where, (v_x, v_y) represents a motion vector.

2.2 OBMC using Multiple Estimators and Shifted Grid

Figure 3 shows the parameters used in the motion estimation and Figure 4 shows the block diagram of the proposed MC-FRUC methods. In the proposed method, two motion estimators (UDME and BDME) are used and FRUC is performed by combining the results obtained by applying several motion compensations. In other words, we performed several motion compensations for each pixel by shifting the macro block by a small amount. Thus, the proposed method produces a new frame by combining several motion compensation results while the conventional MC methods perform just one motion compensation.

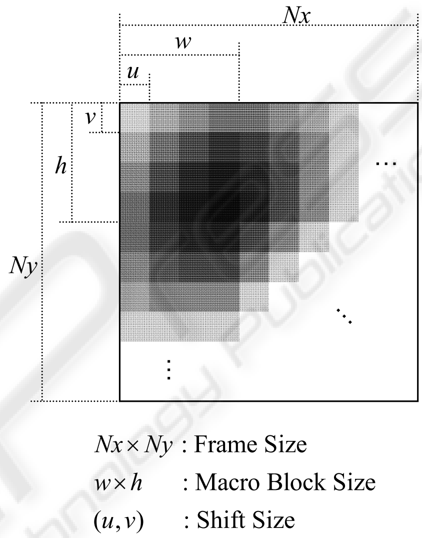

Figure 3: Parameters of the overlapped block estimation.

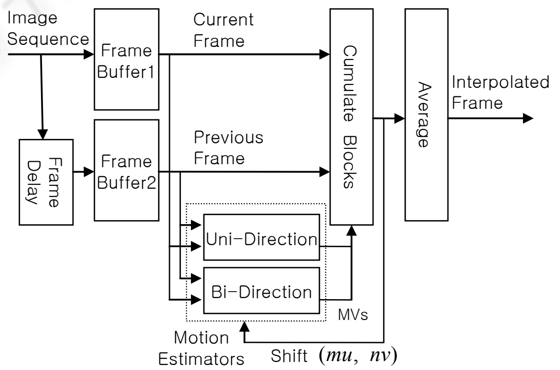

Figure 4: Block diagram of the proposed method.

In the proposed method, the new pixel value of the interpolated frame is obtained by averaging all the overlapped blocks as follows:

$$f^I(x,y) = \frac{1}{|I(x,y)|}\sum_{j \in I(x,y)} B_j^I(x,y) \quad (2)$$

where $I(x,y)$ denotes a set of block indices which contains pixel (x,y):

$$I(x,y) = \{ k \mid (x,y) \in B_k^I \} \tag{3}$$

$|\bullet|$ represents the number of elements of a set, which counts the number of elements of the set. To perform multiple motion compensations, we move the block grid by u (horizontal increment) and v (vertical increment). It is noted that $u<w$ and $v<h$.

3 EXPERIMENTAL RESULTS

The proposed methods were evaluated using two video sequences: “Foreman” with swaying background and complex motions and “Table Tennis” with a stable background and fast motions. The two sequences are CIF and use the YUV420 format.

The n-th interpolated frame is generated from the original (n-1)-th and (n+1)-th frames, and the PSNR between the original and the interpolated n-th frames are calculated to measure the objective quality of the interpolated frames. We first performed motion estimation in the Y channel and use the same motion vectors for the UV channels.

The size of macro block was set to 16×16 and the search ranges for two motion estimators are set to ±16 for the UDME method and ±8 for the BDME method. In spite of the different search ranges, the computational complexities of the two estimators are the same since the BDME method searches motion vectors in half-pixel precision.

Table 1-2 show the performance comparison with various shift sizes. It is noted that the conventional method is the single ME method with $u=w$ and $v=h$ (u:16, v:16).

As can be seen in the tables, the proposed UDME and BDME methods outperformed the conventional method by about 0.5dB in terms of PSNR and showed slight improvement as the shift size was decreased.

The proposed multi-estimator (UD&BD) method showed better results than the single estimators and also provided better performance as the shift size was decreased.

Figure 5 shows sub-images of the interpolated frames of *Table Tennis* when different shift sizes were used. As can be seen in Figure 5, the blocking artifacts were reduced, though some blurring effects appeared as the shift size is smaller.

Table 1: Average PSNR of interpolated frames using the single ME and multiple MEs of *Foreman.*

	u:16, v:16	u:8, v:8	u:4, v:4	u:2, v:2	u:1, v:1
UDME	31.27	31.88	32.04	32.04	31.99
BDME	31.09	31.76	31.90	31.93	31.91
Proposed UD&BD	33.54	34.15	34.29	34.31	34.25

Table 2: Average PSNR of interpolated frames using single ME and multiple MEs of *Table Tennis.*

	u:16, v:16	u:8, v:8	u:4, v:4	u:2, v:2	u:1, v:1
UDME	32.45	33.80	34.12	34.18	34.19
BDME	32.55	33.57	33.81	33.86	33.87
Proposed UD&BD	34.10	35.06	35.27	35.31	35.33

Figure 5: Sub-images of the interpolated frames with various shift sizes of *Table Tennis.* (BDME).

The conventional BDME method produced blocking artifacts and edge degradation in the fast motion area due to unreliable motion estimation. On the other hand, the proposed overlapped methods reduced this problem and provided improved perceptual quality.

Figure 6 shows sub-images of interpolated frames using the single ME and the proposed multiple MEs. As can be seen in Figure 6, the proposed overlapped motion estimation methods substantially removed those blocking artifacts. Also, the proposed methods provided better PSNR.

Figure 6: Sub-images of the interpolated frames of *Foreman.*

Table 3: Comparison of computational complexity of the proposed methods.

	u:16, v:16	u:8, v:8	u:4, v:4	u:2, v:2	u:1, v:1
UDME	1	4	16	64	256
BDME	1	4	16	64	256
Proposed UD&BD	2	8	32	128	512

Table 3 shows the computational complexity ratio of the proposed methods. If we assume the amount of calculation of UDME is 1, the complexity of the small shift size (u:1, v:1) is 256 times larger. Although the overlapped UDME and BDME methods with small shift sizes provided best PSNRs, they suffer from the high implementation cost and complexity.

Table 4 shows the performance comparison and computational complexity of the proposed method and the OBME method (Overlapped Block Motion Estimation) (Ha et al., 2004). As can be seen in Table 4, the proposed method produced better PSNRs and lower complexity than the OBME methods.

Table 4: PSNR and computational complexity of the proposed and OBME (Ha et al., 2004) methods.

PSNR (complexity)	Foreman		Table Tennis	
	(u:16, v:16)	(u:8, v:8)	(u:16, v:16)	(u:8, v:8)
Proposed UD&BD	33.54 (2)	34.15 (8)	34.10 (2)	35.06 (8)
Proposed UD&BD with sub-sampling	32.72 (0.5)	33.32 (2)	33.95 (0.5)	34.96 (2)
OBME	31.46 (4)	31.87 (16)	32.50 (4)	33.29 (16)
OBME with sub-sampling	30.85 (1)	31.24 (4)	32.49 (1)	33.3 (4)

4 CONCLUSIONS

In this paper, we propose a new MC-FRUC algorithm with overlapped motion estimation and compensation. Experimental results show that the proposed methods substantially reduced blocking artifacts and were robust against inaccurate motion estimation.

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