Phase Correlated Bilateral Motion Estimation for Frame Rate Up-Conversion

DongGon Yoo[1], SukJu Kang[2], SungKyu Lee[3], and Young Hwan Kim[4]
Division of Electrical and Computer Engineering
Pohang University of Science and Technology (POSTECH)
San 31 Hyoja-Dong, Nam-Gu, Pohang, Kyungbuk 790-784, Republic of Korea
E-mail: {[1]white309, [2]kangx, [3]kaze, [4]youngk}@postech.ac.kr

Abstract: In this paper, we propose a new motion estimation method. The proposed motion estimation method enhances the image quality by using the temporal symmetry in the phase correlation method. Experimental results show that the average PSNR of the proposed method is up to 1.36 dB higher than that of the benchmark methods. Also, the computation time of the proposed method is very low compared to the benchmark methods.

1. Introduction

Hold-type displays such as liquid crystal displays (LCDs) have a serious problem called motion blur which degrades image quality in moving images as shown in Fig. 1 [1].

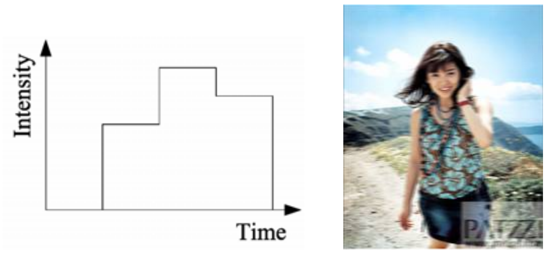


Fig. 1. Temporal response and human perception in LCD

There are several approaches to reduce motion blur. One approach is to imitate the driving method of the impulse-type display such as scanning backlight and black data insertion [2]. These methods reduce motion blur effectively, but they also reduce luminance significantly. Another approach is the frame rate up-conversion (FRUC) which is a technique that increases the frame rate by inserting intermediate frames between original frames. Compared to the above methods, this method has the advantage of maintaining luminance, while reducing motion blur.

The frame rate up-conversion is broadly divided into two steps: motion estimation and motion compensated interpolation, as shown in Fig. 2.

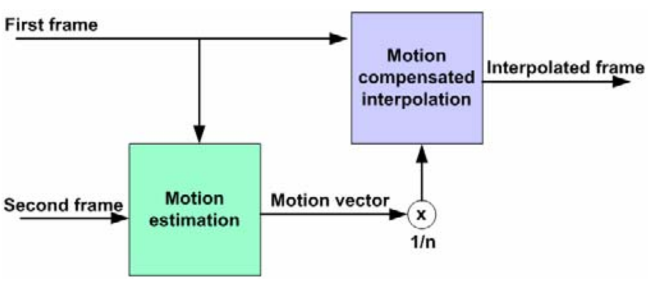


Fig. 2. Motion estimation and motion compensated interpolation

Motion estimation (ME) is the process that calculates the motion vectors (MVs), which are the motion change of objects, in two or more consecutive frames [3],[5]. Motion compensated interpolation (MCI) is the process that creates interpolated frames using the motion vectors obtained in motion estimation and inserts interpolated frames between original frames. The performance of FRUC considerably depends on the ME and the MCI method.

One of the generally used motion estimation methods is the phase correlation method (PCM) because of its high efficiency in terms of the performance over the complexity [4]. The PCM measures the displacement between consecutive frames directly from their phases by using cross correlation and image correlation. The cross correlation obtains the candidate MVs in frequency domain, and the image correlation decides the final MV out of the multiple candidate MVs. However, the PCM is not suitable to find the true motion trajectory on the reference block of the interpolated frame in MCI [6],[7].

This paper shows that the candidate MVs obtained by the cross correlation can apply to the reference block on the interpolated frame in the image correlation step. In addition, we propose the motion estimation method using the temporal symmetry property.

The rest of the paper is organized as follows. Section 2 describes the proposed motion estimation method. Section 3 discusses experimental results. Finally, Section 4 concludes the paper.

2. Proposed motion estimation

The existing PCM has two defects in MCI. One of the defects is caused by motion vector shift in MCI, shown in Fig. 3, because the true MV of the reference block on the interpolated frame can be different with the shifted MV.

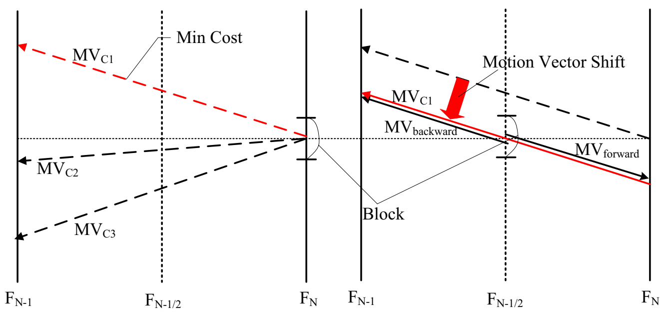


Fig. 3. Error caused by motion vector shift in MCI

Another defect is caused by using the outside pixels of image block in case the selected MVs are large as shown in Fig. 4. The proposed phase correlated bilateral motion estimation (PCB-ME) eliminates two defects.

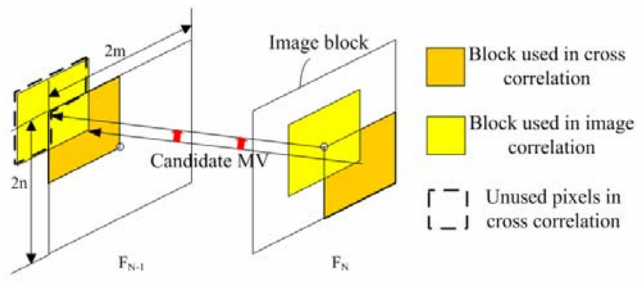


Fig. 4. Error caused by unused pixels in cross correlation

2.1 Cross correlation

In this chapter, we calculate the cross correlation and show the candidate MVs obtained by cross correlation can apply to the reference block on the interpolated frame in the image correlation step. First, we calculate the discrete Fourier transform of given two input images, which are '2m'x'2n' size block, and calculate the cross-power spectrum, shown in (1), (2).

$$I^n_{i,j} = F\{i^n_{i,j}\},\ I^{n-1}_{i,j} = F\{i^{n-1}_{i,j}\} \quad (1)$$

$$R_{i,j} = \frac{I^n_{i,j} I^{n-1*}_{i,j}}{\left| I^n_{i,j} I^{n-1*}_{i,j} \right|} \quad (2)$$

Then, we apply the inverse discrete Fourier transform to $R_{i,j}$, and obtain the normalized cross correlation, $r_{i,j}$, as shown in (3). Fig. 5. illustrates the nomalized cross correlation map to each x and y axis dispacement.

$$r_{i,j} = \left| F^{-1}\{R_{i,j}\} \right| \quad (3)$$

Finally, we obtain the set of candidate MVs $\{dx, dy\}_{i,j}$ from the nomalized cross correlation. The set of candidate MVs includes '2m'x'2n'x'C' MVs, where C is the ratio of the number of the candidate high peaks to the number of total peaks in the correlation map.

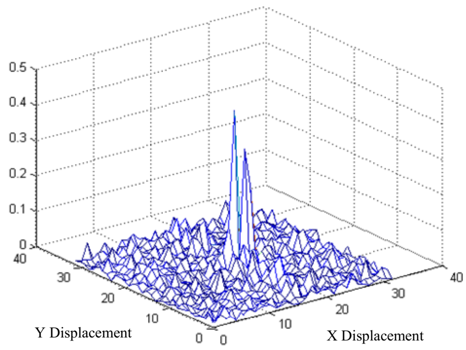


Fig. 5. Normalized cross correlation map

In the process of the cross correlation, the correlation value for each displacement of the nomalized cross correlation map is obtained by using the inside blocks of image blocks in the previous and current frames as shown in Fig. 6. The inside blocks in the previous and current frames have temporal symmetry property from the viewpoint of the reference block on the interpolated frame. Therefore, the candidate MVs selected by the correlation value can apply to the reference block on the interpolated frame, while the existing PCM applies the MVs to the reference block on the current frame.

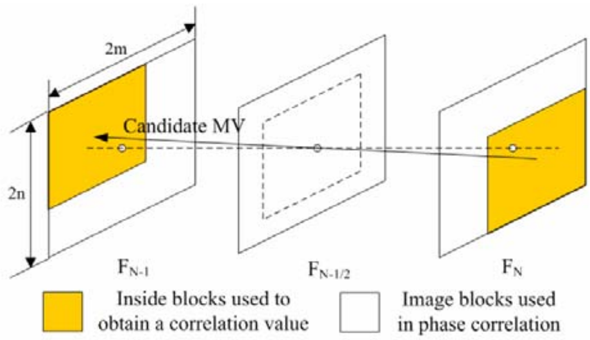


Fig. 6. Temporal symmetry of the cross correlation

2.2 Image correlation

The proposed image correlation picks out one MV of the candidate MVs by using temporal symmetry property as shown in Fig. 7. To select the final MV, we calculate the sum of bilateral absolute difference (SBAD), the absolute difference of pixels between two candidate blocks in the previous and current frames, and then select the final MV that minimizes the SBAD, shown in (4).

$$SBAD(B_{i,j}, v_c) = \sum_{s \in B_{i,j}} \left| F_{n-1}(s - v_c) - F_n(s + v_c) \right|$$
$$v_{i,j} = \arg \min_{(dx,dy) \in v_c} \{SBAD(B_{i,j}, v_c)\} \quad (4)$$

,where $B_{i,j}$ is the reference block on the interpolated frame, and v_c is a set of candidate MVs.

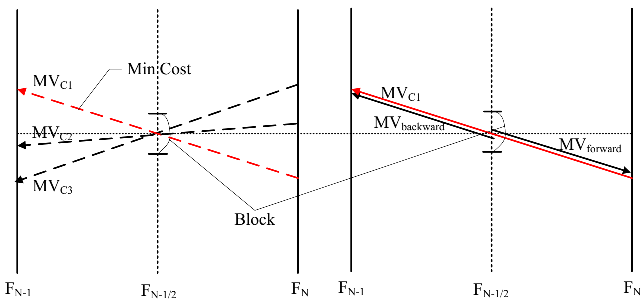


Fig. 7. The image correlation in the proposed motion estimation

3. Experimental results

In this paper, we performed two experiments. First, we evaluated the performance of the proposed method. Fig. 8 illustrates the architecture of the benchmark and proposed method.

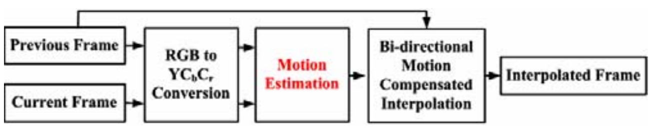
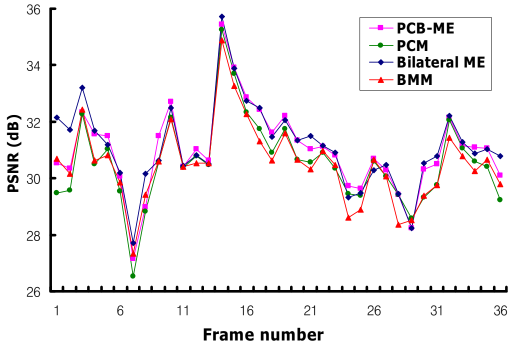
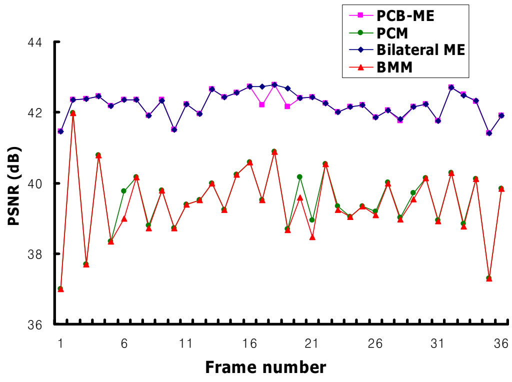


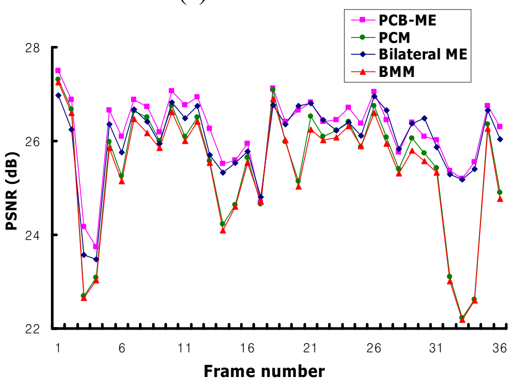
Fig. 8. The architecture of the benchmark and the proposed method



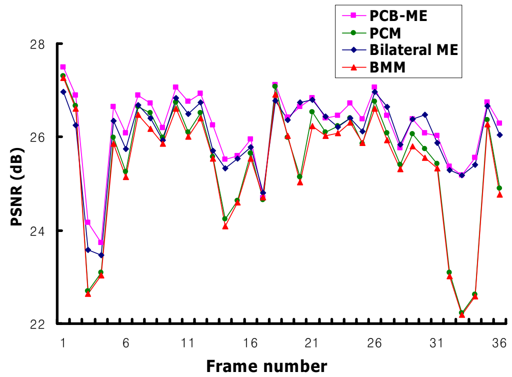
(a) *Foreman*



(b) *Container*



(c) *Flower garden*



(d) *Akiyo*

Fig. 9. PSNRs by the benchmark methods and the proposed method for test sequences: (a) *Foreman*, (b) *Container*, (c) *Flower garden*, and (d) *Akiyo*

First, we performed RGB-to-YC_bC_r color space conversion to use Y signal, which means luminance, in ME. Then, we used several motion estimation methods, which are block matching method (BMM), bilateral ME, and PCM, as benchmark methods, and used the PCB-ME as a proposed method. A bidirectional MCI, which uses both the previous and the current frames, was used for MCI step.

The experiment conditions are as follows. We devided the current frame into 16x16 size blocks to perform the ME and the MCI. In the case of the cross correlation of the PCM and the PCB-ME, we used enlarged blocks, which were 32x32 size blocks centered around formely defined 16x16 size blocks. The ratio C is 1%. The search range was set to -16/16 pixels for both vertical and horizontal directions. We used 4 test sequences: *Foreman*, *Container*, *Akiyo*, and *Flower garden*, which are in the standard CIF (352x288) format. For 73 consecutive frames for each test sequences, we removed 36 even frames and constructed 36 new even frames from the 37 odd frames.

In the first experiment, we evaluated the performance of the proposed method and the benchmark methods. As the performance metric, we used peak signal to noise ratio (PSNR), defined in (5).

$$\text{PSRN} = 10\log\frac{255^2}{\frac{1}{N}\sum_{i=1}^{row}\sum_{j=1}^{col}(I(i,j)-I_R(i,j))^2} \qquad (5)$$

,where I is the original image, I_R is the reconstructed image, N is the number of pixels in the image.

The results are compared in Fig. 9. The figure indicates that the PCB-ME and the bilateral ME have similar performance and outperform the PCM and the BMM. Table 1 summarizes the average PSNRs of the benchmark and the proposed methods. The table indicates that the average PSNRs of the PCB-ME and bilateral ME are almost equal, but the proposed method outperformed the other benchmark methods in all test sequences. The average PSNR of the proposed method was up to 1.36 dB higher than those of the benchmark methods.

Table 1. Average PSNRs of 36 frames for Foreman, News, Akiyo, Container, and Flowergarden

Average PSNRs (dB)				
	BMM (ref.)	PCM	Bilateral ME	PCB-ME
Foreman	30.53	30.56	31.13	31.00
Container	39.43	39.44	42.23	42.20
Flowergarden	25.40	25.47	26.03	26.21
Akiyo	42.67	42.70	44.05	44.07
Gain	0	0.03	1.35	1.36

Second, we estimated the average computation time of the proposed and the benchmark methods using all test sequences (each has 73 frames). As shown in Table 2, the average computation time of the proposed PCB-ME is very low compared to that of the BMM and the bilateral ME, however is slightly lager than that of the PCM.

Table 2. Average computation time of the proposed method and benchmark methods

Average Computaiton Time (s)				
	BMM (ref.)	PCM	Bilateral ME	PCB-ME
Computation Time	7.91	0.74	2.70	1.13
Ratio	100%	9%	34%	14%

4. Conclusion

In this paper, we proposed a new motion estimation method. The proposed motion estimation method enhanced the image quality by using the temporal symmetry in the phase correlation. In experimental results, The proposed phase correlated bilateral motion estimation provided the PSNR improvement of up to 1.36 dB, when compared to the benchmark methods. Also, the computation time of the proposed method is very low compared to the benchmark methods.

Acknwledgements

This work was supported by IDEC, BK21, and LG Display Company.

References

[1] T. Kurita, “Moving picture quality improvement for hold-type AM-LCDs,” SID'01 Digest, pp.986.989, 2001

[2] K. Sekiya and H. Nakamura, “Eye-trace integration effect on the perception of moving pictures and a new possibility for reducing blur on hold-type displays,” SID ’02 Digest, pp 930-933, 2002

[3] F. Dufaux and F. Moscheni, “Motion Estimation Techniques for Digital TV: A Review and a New Contribution”, Proc. IEEE, vol. 83, no. 6, pp. 858-876, June 1995.

[4] S. J. Kang, D. G. Yu, and Y. H. Kim, ”Phase Correlation-Based Motion Estimation Using Variable Block Sizes for Frame Rate Up-Conversion,” The 22nd ITC-CSCC, Busan, Korea, July 8-11, 2007.

[5] R. Castagno, P. Haavisto, and G. Ramponi, “A Method for Motion Adaptive Frame Rate Up-Conversion”, IEEE Trans. on Circuits and Systems for Video Technology, vol. 6, no. 5, Oct. 1996.

[6] S. J. Kang, K. R. Cho, and Y. H. Kim, "Motion Compensated Frame Rate Up-Conversion Using Extended Bilateral Motion Estimation," IEEE Transactions on Consumer Electronics , Vol. 53, Issue 4, pp. 1759-1767, Nov. 2007.

[7] B.D. Choi, J.W. Han, C.S. Kim, and S.J. Ko, “Motion-Compensated Interpolation Using Bilateral Motion Estimation and Adaptive Overlapped Block Motion Compensation”, IEEE Transations on Circuits and Systems of Video Technology, vol. 17, no. 4, pp. 407-416, Apr. 2007