A Temporal Error Concealment Technique Using Motion Adaptive Boundary Matching Algorithm

Wonki Kim* and Jechang Jeong*
* Division of Electrical and Computer Engineering, Hanyang University, Seoul, 133-791, Korea
Tel : +82-2-2292-6457 Fax : +81-2-2281-9912 E-mail: {stwon, jjeong}@ece.hanyang.ac.kr

Abstract: To transmit MPEG-2 video on an erroneous channel, a number of error control techniques are needed. Especially, error concealment techniques which can be implemented on receivers independent of transmitters are essential to obtain good video quality. In this paper, a motion adaptive boundary matching algorithm (MA-BMA) is presented for temporal error concealment. Before carrying out BMA, we perform error concealment by a motion vector prediction using neighboring motion vectors. If the candidate of error concealment is not satisfied, search range and reliable boundary pixels are selected by the motion activity or motion vectors and a damaged macroblock is concealed by applying the MA-BMA. This error concealment technique reduces the complexity and maintains PSNR gain of 0.3 0.7dB compared to the conventional BMA.

Keywords: Error Concealment, Boundary Matching Algorithm, Post-Processing, MPEG-2.

1. INTRODUCTION

In transmitting MPEG-2 video over wireless or error-prone communication networks, a number of error control techniques are needed. In particular, error concealment in video communications is intended to recover loss of information, using available image data [1]. It is therefore to be implemented on receivers to present more visually pleasing video.

A number of methods have been developed to conceal errors in video communication, e.g., adaptive interpolation in the spatial, temporal, and frequency domains. Among them, temporal concealment techniques [2-4] are important which exploit temporal redundancy. Thus motion vectors (MVs) are highly significant for error concealment. In this case, many methods have been proposed to recover the motion vectors to improve the decoded video quality, which generally use the MVs of neighboring macroblock (MB) for motion estimation. There are two solutions to interpolate the missing MVs: the first one selects a predefined MV from a set of candidates [5, 6]. The second solution searches for the MV which satisfies best the spatial coherence criterion, based on the boundary matching algorithm (BMA) [9, 10].

Error concealment methods mentioned above that are based on block- or macroblock-loss, use data on top, bottom, right and left directions of lost macroblock or block neighbor. However, most severe errors appear on a slice basis, then right and left data are not available. In detail, if one block's variable length coded motion vector is lost by burst error, the effect of one erroneous block is spread out to the end of underlying slice in spatial domain. In addition, motion compensation scheme use the previous frame, erroneous block has an influence on afterward frames until the next new intra-coded frame appears.

Improvement of the BMA has been proposed [7, 8, 12], but these approaches unavoidably introduce larger latency in addition to requiring extra memory for decoding. Therefore this paper proposes a framework of motion adaptive boundary matching algorithm (MA-BMA) that is more effective and of better performance than the conventional BMA.

The paper is organized as follows. The boundary matching algorithm is first briefly reviewed in Section 2. Section 3 presents in detail the proposed MA-BMA. Experimental results are given in Section 4. Finally, Section 5 concludes the work.

2. BOUNDARY MATCHING ALGORITHM(BMA)

The BMA exploits the fact that adjacent pixels in a video picture exhibit high spatial correlation [9, 10] It takes the lines of pixels above, below, left and right of the lost macroblock in the current picture and uses them to surround each candidate block from the previous decoded picture. It then calculates the total squared difference between these four lines and the corresponding four lines on the edge of a 16x16 block of data within a previous decoded picture. This is illustrated in Fig. 1. The BMA estimates the lost motion vector as the one in which the squared difference between the surrounding lines (from the current decoded picture) and the block (from the previous decoded picture) is minimum. Referring to Fig. 1, this means we minimize the total squared difference, D_T, calculated by summing the four squared differences defined in eq. (1). Where the top-left pixel (m, n) denotes the first pixel of N×N lost MB, and $\hat{x}$ is the MB of the reference frame.

$$D_L = \sum_{i=0}^{N-1} \left| \hat{x}(m-1, n+i) - x(m-1, n+i) \right|$$

$$D_R = \sum_{i=0}^{N-1} \left| \hat{x}(m+N, n+i) - x(m+N, n+i) \right|$$

$$D_T = \sum_{i=0}^{N-1} |\hat{x}(m+i,n-1) - x(m+i,n-1)|$$

$$D_B = \sum_{i=0}^{N-1} |\hat{x}(m+i,n+N) - x(m+i,n+N)| \quad (1)$$

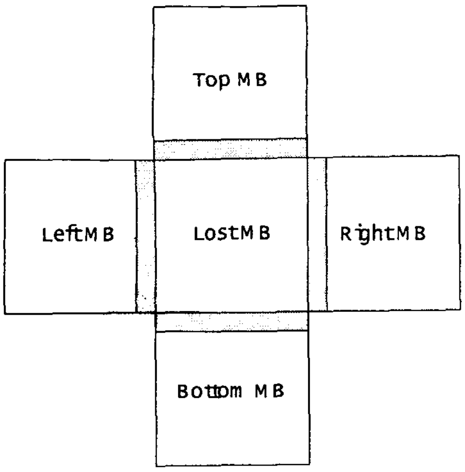


Fig. 1. BMA (Boundary Matching Algorithm)

This technique has some limitations. In the first place, very often all four of these lines are not available for matching when cell loss occurs. And although this works well in the areas involving similar or small motion, it fails when the damaged macroblock is in the regions containing rotational movements, zooming, and deformation of objects, or incoherent motion. Finally, because of performing full search, BMA has a problem of high computational complexity.

3. MOTION ADAPTIVE BMA(MA-BMA)

The framework of proposed temporal error concealment algorithm is composed of motion vector prediction and MA-BMA. First, backgrounds or still regions are concealed by motion vector prediction without the complicated BMA. And regions of small or similar motion are recovered by BMA with small search range. Finally, areas involving large or complex motion are reconstructed by MA-BMA using new reliable boundary pixels with full search range. Fig. 2 shows the block diagram of the proposed error concealment algorithm.

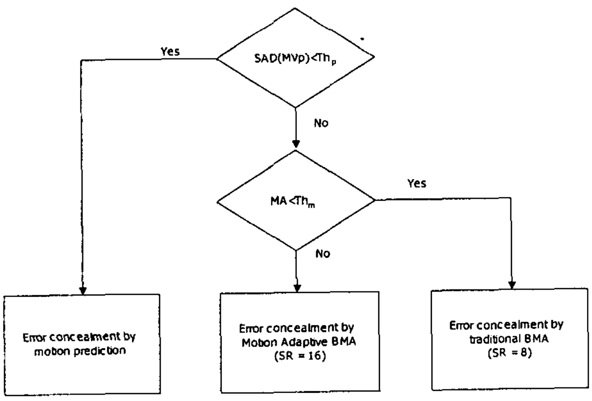


Fig. 2. The proposed error concealment algorithm

3.1. Motion vector prediction

The first step selects a predefined MV from a set of candidates. MV candidates may include: Zero MV, neighboring MVs, Collocated MV and Average/Median MV [5, 6], and Global MV. We estimate the Global MV by putting all nonzero MVs for the current frame into a histogram. The histogram bin with the largest count is assumed to represent the global motion. If the minimum SAD for MV_p is less than Th_p, we reconstruct the damaged MB using this MV_p. Otherwise, we go to the next step.

3.2. Motion Activity

For a damaged macroblock, let MV_j(j=0,..., 5) denote the motion vectors of its six adjacent MBs, i.e., top-left, top, top-right, bottom-left, bottom, bottom-right, respectively, to the damaged macroblock. The motion activity (MA) of the damaged area is then quantified by

$$MA = \frac{1}{15}\sum_{j=0}^{5}\sum_{i=j+1}^{5}(|MV_{xj} - MV_{xi}| + |MV_{yj} - MV_{yi}|) \quad (2)$$

In the case that MA does not exceed a threshold (Th_m), it is assumed that the surrounding area of the lost MB contains slow motion or translational motion. In this case, the standard BMA is used to estimate the MV of the lost macroblock. But search range is smaller than the conventional method. Otherwise, i.e., $MA>Th_m$, the error concealment algorithm steps into the search of the reliable boundary pixels.

3.3. Selection of reliable boundary pixels

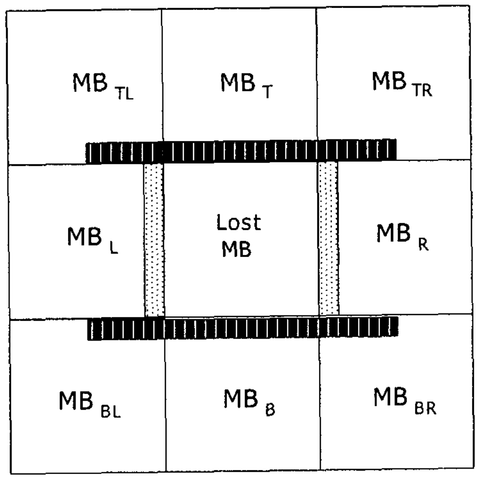


Fig. 3. MA-BMA for slice error

The reliable boundaries used for error concealment are decided by neighboring MVs. Above all, if $avgMV_T > avgMV_B$, we use all samples of upper boundary and 1/2 down samples of lower boundary, and vice versa. This process is equivalent to the case that a block boundary of larger motion is weighted. That is, generally a region of large motion is more important than the background or inner static region of an object.

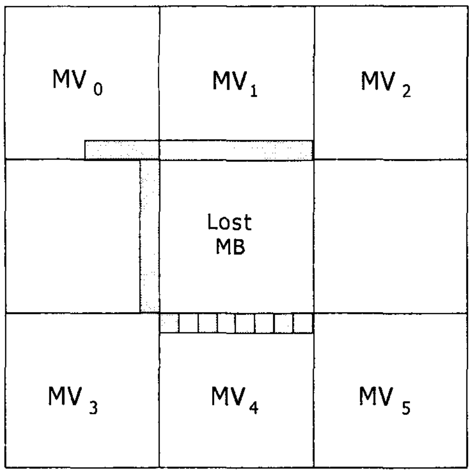


Fig. 4. An example of MA-BMA when the damaged MB is positioned at left horizontally, $avgMV_T$ > $avgMV_B$, and $diffMV_T$ > 3.

$$avgMV_T = \frac{1}{3}\sum_{j=0}^{2}(|MV_{xj}| + |MV_{yj}|),$$
$$avgMV_B = \frac{1}{3}\sum_{j=3}^{5}(|MV_{xj}| + |MV_{yj}|), \qquad (3)$$

By $diffMV_T$ and $diffMV_B$ in eq. (4), the boundary extension is achieved. If $avgMV_T > avgMV_B$, and $diffMV_T > 3$, then motion of MB_{TL} is larger than MB_{TR}'s. This means that the boundary of MB_{TL} more important than that of MB_{TR}. Therefore the boundary is extended toward left. And according to horizontal position of the MB, left or right boundary is used (refer section 3.4).

$$diffMV_T = (|MV_{0x}| + |MV_{0y}|) - (|MV_{2x}| + |MV_{2y}|), \qquad (4)$$
$$diffMV_B = (|MV_{3x}| + |MV_{3y}|) - (|MV_{5x}| + |MV_{5y}|)$$

In particular, if upper or lower MB is intra-coded, we do not use the boundary of intra-coded block. For this reason, intra-coded MB is not likely to exist in the previous frame. Fig. 3, 4 are the structure of MA-BMA.

3.4. MV recovery

The processing starts with MB columns at the frame boundaries and then moves inwards on column-by-column basis [11]. This processing order helps prevent a typical concealment mistake that is made in the usually "difficult" (discontinuous motion areas, large coded prediction error) part of the frame from propagating to the "easy" (continuous motion area, similar motion over several frames) parts of the frame.

4. SIMULATION RESULTS

The experimental results shown in this section demonstrate that improved quality has been achieved by the proposed error concealment technique which is suitable for slice-based loss. For this purpose, the results for the configuration of slice loss are reported. The MV prediction and MA-BMA are simulated. For performance comparison, the standard BMA and Zero MV (copying the macroblock at the same location from the reference frame) are used.

Test sequences of SIF resolution (352×240) characterized by different spatial and temporal activities have been used in the performance evaluation. The options of MPEG-2 encoding are GOP structure of 'IP', 30 fps, 1Mbps, and MP@ML.

The damaged frame is generated by dropping odd rows of the macroblocks in the image, and the reference frame is assumed to be error free. In the experiments, this process is repeated for about 100 frames for each sequence.

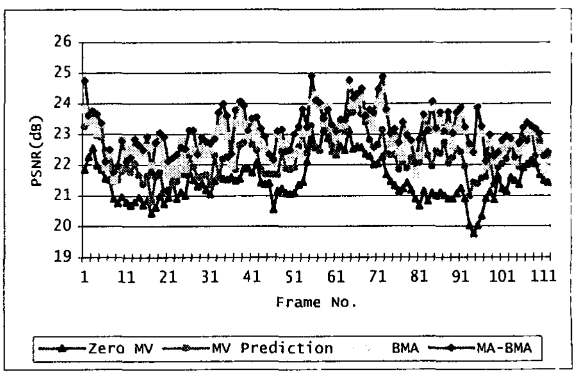
In the simulations, the parameters are set as follows: Th_p=0.2 for determining whether the error concealment is performed by motion prediction, Th_m=3 for deciding the motion activity of the damaged area. If Th_p is increased, the error concealment is faster, but image quality is worse. And if Th_m is increased, the conventional BMA is used more.

Fig. 5 presents the PSNR results of the error concealed frames from different sequences using the above approaches. In general, the proposed MA-BMA brings improvement on the overall performance over the competing algorithms. As summarized in Table 1, the MA-BMA achieves an average PSNR gain of up to 0.3~0.7 dB over the BMA. And if the Motion Activity is less than Th_m, search range is 8. Otherwise, search range is 15.

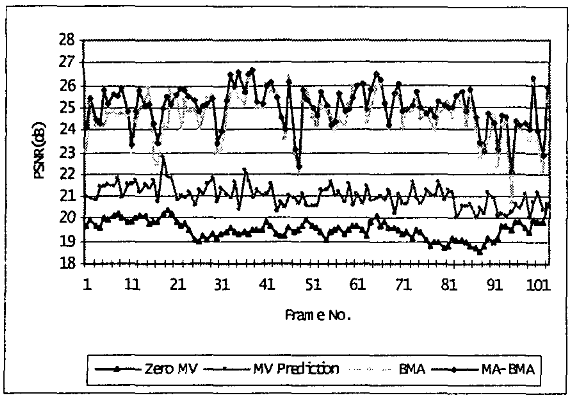
In addition to the improved quantitative quality, the visual quality of the images produced by the proposed MA-BMA is much better than those obtained by the other techniques. Fig. 6 shows the error concealment results of Football sequence. In this case, the proposed MA-BMA produces the resultant frame more visually pleasing with less noticeable reconstruction artifacts. Better visual quality has also been observed in the other test video sequences concealed by the proposed technique.

Table 1. Average PSNR results (dB) of luminance for different sequences

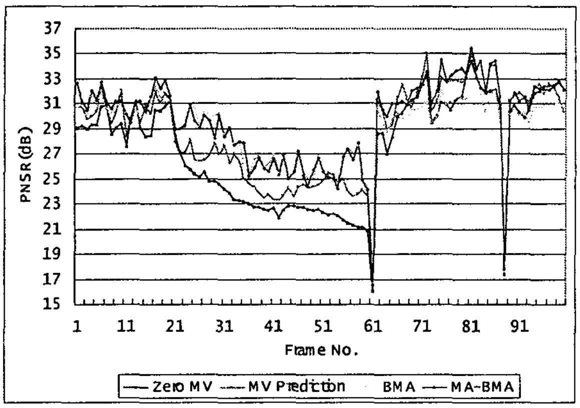
Sequences	PSNR(dB)			
	Zero MV	MV Prediction	BMA	MA-BMA
Football	21.46	22.24	23.07	23.35
Flower garden	19.52	21.01	24.59	25.00
Table tennis	27.43	28.73	29.04	29.75



a. Football



b. Flower Garden



c. Table Tennis

Fig. 5. PSNR performance for different algorithms

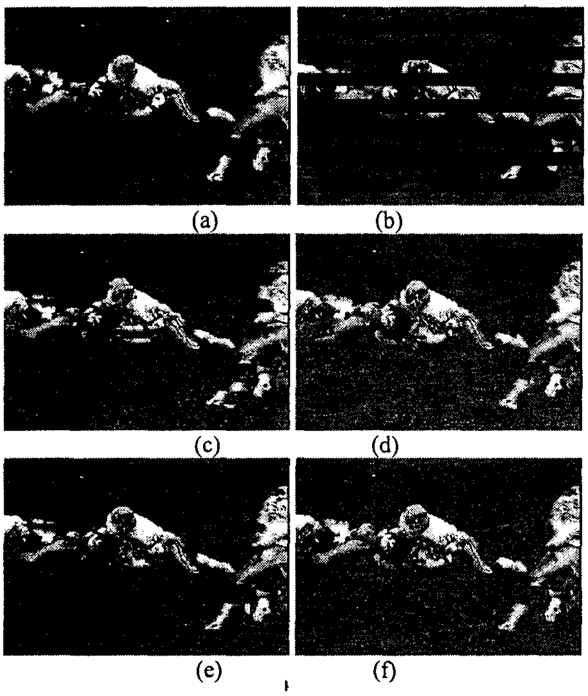


Fig. 6. Simulation results for the football sequence: (a) original frame, (b) damaged frame, reconstructed frames by (c) Zero MV, (d) BMA, (e) MV prediction, and (f) MA-BMA, respectively.

5. CONCLUSION

An adaptive technique based on the boundary matching algorithm has been proposed in this paper for temporal error concealment in MPEG-2 video. By using the MV prediction and MA-BMA together, the proposed algorithm is in a sense a tradeoff between complexity and performance. Search range and reliable boundary pixels are selected by the motion activity or motion vectors and a damaged macroblock is concealed by applying the MA-BMA. This error concealment technique reduces the complexity and maintains PSNR gain of 0.3 0.7dB compared to the conventional BMA.

References

[1] Y. Wang and Q. F. Zhu, "Error control and concealment for video communications: A review," Proceedings of the IEEE, vol. 86, pp. 974-997, May 1998.

[2] M. Ghanbari and V. Seferidis, "Cell-loss concealment in ATM video codecs," IEEE Trans. Circuits Syst. Video Technol., vol. 3, no. 3, pp.238-247, 1993.

[3] M. Wada, "Selective recovery of video packet loss using error concealment," IEEE J. Select. Areas Commun., vol. 7, no. 5, pp. 807-814, 1989

[4] L. H. Kieu and D. N. Ngan, "Cell-loss concealment techniques for layered video codecs in an ATM networks," IEEE Trans. Image Processing, vol. 3, no. 5, pp. 666-677, 1994.

[5] J. Suh and Y. Ho, "Recovery of motion vectors for error concealment," IEEE TENCON, pp.750-753, June 1999.

[6] D. Kwon and P. Driessen, "Error Concealment Techniques for H.263 Video Transmission," IEEE, pp.276-279, February 1999.

[7] Young H. Jung, Yong-goo Kim, and Yoonsik Choe, "Robust error concealment algorithm using iterative weighted boundary matching criterion," Proc. ICIP, pp.384-387, 2000

[8] Y. C. Lee, Y. Altunbasak, and R. Mersereau, "A temporal error concealment method for MPEG coded video using multi-frame boundary matching algorithm," in Proc. ICIP, vol. 1, pp. 990-993, 2001.

[9] Jian Feng, Kwok-Tung Lo and Hanssna Mehrpour, "Error concealment for MPEG video transmissions," IEEE Trans. Consumer Electronics, vol43, No2, pp.183-187, 1997.

[10] W.M. Lam, A.R. Reibman and B. Siu, "Recovery of lost or erroneously received motion vectors," Proceedings of ICASSP, pp.417-420, April 1993.

[11] Ye-Kui Wang, Miska M. Hannuksela and Viktor Varsa, "The error concealment feature in the H.26L test model," IEEE ICIP, pp.729-732, 2002.

[12] Tao Chen, Ximin Zhang, Yun-Qing Shi, "Error concealment using refined boundary matching algorithm," ITRE2003, pp.55-59, 2003.