

## Temporal Error Concealment Using Recursive Boundary Matching Method

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**Abstract:** In this paper, we proposed a temporal error concealment (EC) using recursive boundary matching method. The proposed recursive boundary matching method improves the spatial correlation of the macroblocks (MBs) by reusing the pixels of the concealed MB and control weighting factor of the concealed MB recursively. And proposed algorithm has both forward concealment and backward concealment to prevent error propagation. Experimental results show that proposed algorithm gives better results than the conventional algorithms from a subjective and an objective viewpoint.

### 1. Introduction

For anchor frames (I- or P-frame), transmission errors corrupt not only the current decoded frame but also the succeeding decoded frame because of the error propagation by temporal prediction. It is because if the variable length coding (VLC) is used, bit errors can desynchronize the coded information such that many following bits are not decodable until the next synchronization codeword appears [1]. Especially, subjective image quality is more severe when the bit error is occurred with slice unit. Error concealment (EC) methods, techniques to combat bit errors and to preserve the image quality, have been proposed [2]-[4].

One way of the EC method is using zero motion vector (ZMV). In this method, a damaged macro block (MB) is simply replaced by the corresponding MB in the reconstructed previous frame. Lam et al. [5] proposed a boundary matching algorithm (BMA) to estimate the lost MB based on a high spatial correlation between adjacent pixels. The drawback of this method is that boundary information may be not sufficient to estimate the motion vector (MV) accurately, especially if the left and below MBs are not available.

Zhang et al. [6] proposed a decoder motion vector estimation (DMVE) extending boundary matching lines of a BMA to estimate of a BMA to estimate the lost MV. The BMA using one pixel boundary line of the above, below, and left is not sufficient in matching the lost entire MB. Therefore, boundary outer several pixel lines (one to eight) and a variable search area are used in a DMVE. However, like BMA, there are blocking effects in the error concealed frame and does not properly work in the regions with motion.

An effective EC algorithm using the initial MV and the modified BMA is proposed. In a BMA using the correlation

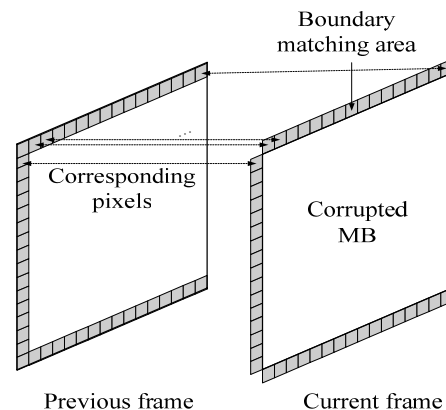


Fig. 1. Matching area of BMA method.

between neighboring pixels, the position of the searching area is important to reduce the matching area and compensate the corrupted MB using the MB with the smallest matching error. After the lost MB is split into four blocks the initial MV is determined by the zero MV and the MV of the blocks that is estimated by block-based motion estimation. Though the correlation between neighboring pixels is high, the outer boundary lines for a BMA are not sufficient in many cases. Therefore, the corrupted area is concealed by the modified BMA that takes not only the inner but also outer boundary lines. Experimental results show that the proposed algorithm provides better results than the conventional algorithm from both the subjective and objective viewpoints.

### 2. Proposed Error Concealment Algorithm

Proposed error concealment algorithm used both forward concealment and backward concealment to prevent error propagation. The proposed recursive boundary matching method improves the spatial correlation of the macroblocks (MBs) by reusing the pixels of the concealed MB and control weighting factor of the concealed MB recursively. Weighting factor means rate of block matching error in concealed region. If it uses weighting area with high rate, concealed MB will have much block error. And if it uses weighting area with low rate, that will cause blocking artifact. So proposed error concealment algorithm uses rate of weighting area with recursive method.

#### 2.1 Forward and Backward Error Concealment

If the lost MB is consecutive, the search area position in the BMA is important for the exact boundary matching. In spite

of error concealment, concealed blocks have block error such as serious blocking artifact. This cause normal temporal error concealment prevent error propagation with forward error concealment. In case one direction error concealment, it accumulates block error. Normal temporal error concealment is shown as Fig. 2.

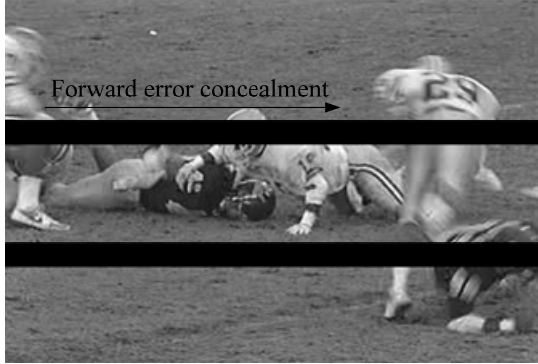


Fig. 2. Normal temporal error concealment.

Therefore, our algorithm use both forward and backward error concealment to prevent error accumulation. Matching area for forward and backward error concealment is shown as Fig. 3. Forward error concealment conceals block error from left to right using matching area of Fig. 3. (a). Backward error concealment conceals block error from right to left using matching area of Fig. 3. (b).

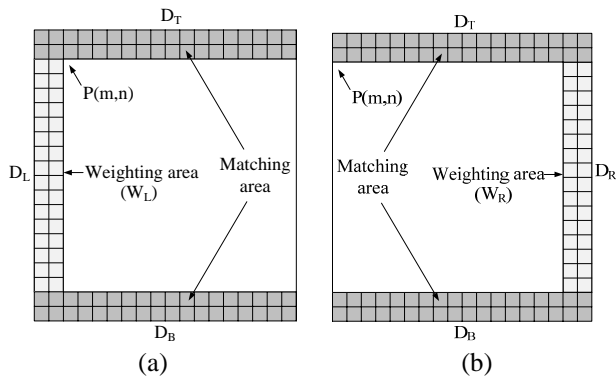


Fig. 3. Matching area for (a) forward error concealment and (b) backward error concealment.

Let a corrupted MB with the size of  $N \times N$ , its top left corner be denoted by  $(m, n)$ , and its intensity is denoted by  $p(m, n)$ . We define  $D_L, D_R, D_T,$  and  $D_B$  as boundary difference value of left, right, top, and bottom area respectively.  $W_L$  and  $W_L$  are weighting factor used in concealed region for respect case. That has double value from 0.5 to 1. This factor is introduced in section 2.2 again. Forward error concealment uses sum of  $D_L, D_T,$  and  $D_B$  among that. Forward error concealment is calculated by the following equation.

$$D_L = \sum_{i=0}^{N-1} \sum_{j=0}^1 W_L |\hat{p}(m+i, n-2+j) - p(m+i, n-2+j)|$$

$$D_T = \sum_{i=0}^1 \sum_{j=0}^{N-1} |\hat{p}(m-2+i, n+j) - p(m-2+i, n+j)|$$

$$D_B = \sum_{i=0}^1 \sum_{j=0}^{N-1} |\hat{p}(m+16+i, n+j) - p(m+16+i, n+j)|$$
(1)

The summation of boundary differences  $D_{FOR}$  is

$$D_{FOR} = D_L + D_T + D_B$$
(2)

Above equation is created by matching area of Fig. 3. (a). Backward error concealment uses sum of  $D_R, D_T,$  and  $D_B$  among that. Backward error concealment is calculated by the following equation.

$$D_R = \sum_{i=0}^{N-1} \sum_{j=0}^1 W_R |\hat{p}(m+i, n+16+j) - p(m+i, n+16+j)|$$

$$D_T = \sum_{i=0}^1 \sum_{j=0}^{N-1} |\hat{p}(m-2+i, n+j) - p(m-2+i, n+j)|$$

$$D_B = \sum_{i=0}^1 \sum_{j=0}^{N-1} |\hat{p}(m+16+i, n+j) - p(m+16+i, n+j)|$$
(3)

The summation of boundary differences  $D_{BACK}$  is

$$D_{BACK} = D_L + D_T + D_B$$
(4)

Above equation is created by matching area of Fig. 3. (b). Our algorithm chooses MB that minimizes boundary differences for forward and backward error concealment respectively.

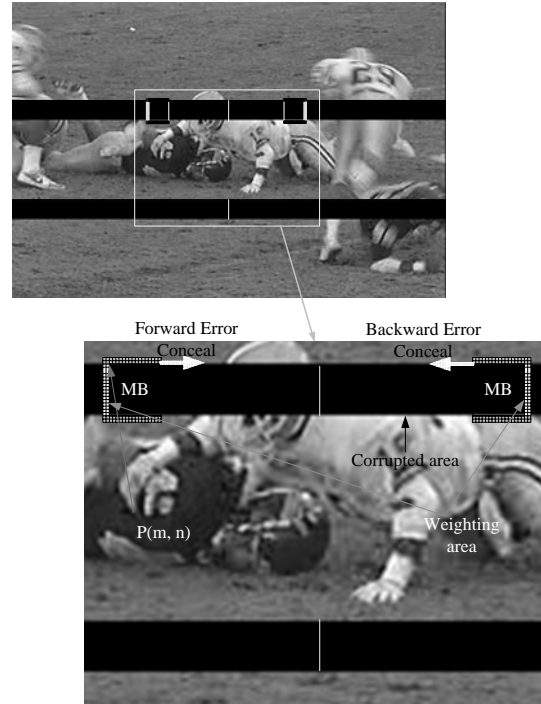


Fig. 4. Forward and backward error concealment.

Example of forward and backward error concealment is shown as Fig. 4. Forward and backward error concealment are performed together to prevent error accumulation. Forward error concealment conceals block error from left to right using matching area and backward error concealment conceals block error from right to left using matching area.

## 2.2 Recursive Error Concealment

Important factor of recursive error concealment is concerned about weighting factor  $W_L$  and  $W_L$  introduced at section 2.1. Weighting area in Fig. 2 is already concealed region and that region has block error. It can't use that with same rate like  $D_T$  and  $D_B$  of matching area. Therefore that must be used adatively. If It uses weighting area with same rate like  $D_T$  and  $D_B$ , concealed MB will have much block error. And If it uses weighting area with low rate, that will cause blocking artifact. So proposed error concealment algorithm uses rate of weighting area with recursive method. Method of recursive error concealment is shown as Fig. 4. Fig. 5 is example of recursive method about forward error concealment. In case backward,  $D_{FOR}$  and  $W_L$  are replaced with  $D_{BACK}$  and  $W_R$ . Weighting factor  $W_L$  is set to 1 at first. And then  $D_{FOR}$  is calculated. If present  $D_{FOR}$  is smaller than previous  $D_{FOR}$ ,  $D_{previous\_FOR}$ , Weighting factor  $W_L$  is set to  $W_L$  minus 0.1 and  $D_{FOR}$  is set to  $D_{previous\_FOR}$ . And then  $D_{FOR}$  is calculated again. If calculated  $D_{FOR}$  is not smaller than  $D_{previous\_FOR}$ , recursive algorithm is stopped. Recursive method like this find MB with reduced error.

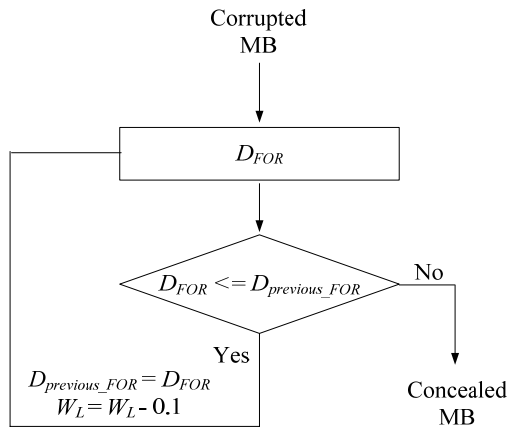


Fig. 5. Recursive error concealment.

## 3. Experiment Results

In order to test the performance of the proposed EC algorithm, computer simulations were run on three test video sequences, which are FOOTBALL, FLOWER GARDEN, and TABLE TENNIS. FOOTBALL and FLOWER GARDEN are  $352 \times 240$  pixels per frame, and they are coded using the MPEG-2 encoder at 4 Mbps at 30

frames/sec. TABLE TENNIS are  $352 \times 288$  pixels per frame, and they are coded using the MPEG-4 encoder at  $QP = 5$  Mbps, 112 kbps, and 15 Hz. The described EC algorithms used  $[-8, 8]$  search area. The peak signal-to-noise ratio (PSNR) was adopted for objective measurement. The MB error rate (MBER) was 20% and 26%, respectively.

The PSNR of the frame, which is reconstructed by conventional algorithms and the proposed algorithm, is shown in Table 1. We observed that proposed algorithm produced higher PSNR values than the conventional algorithms. Blocking artifact is created in FOOTBALL using BMA and DMVE and rough boundary is created in FOOTBALL using ZMV as Fig. 6. Object deformation is created in TABLE TENNIS using BMA but result of BMA method is fine as Fig. 7. Blocking artifact is created in FLOWER GARDEN using ZMV and DMVE but result of BMA method is fine as Fig. 8. Proposed algorithm shows fine boundary matching in three video sequences. Experimental results clearly show that the frame reconstructed by the proposed algorithm have smooth MB boundary. Proposed algorithm has better performance compared with conventional algorithms in terms of objective and subjective image quality.

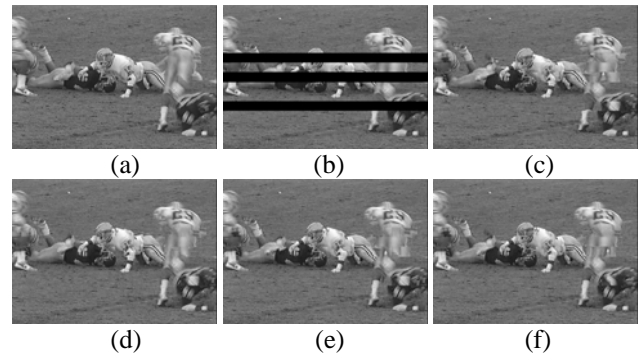


Fig. 6. (a) The original image and (b) the error image and concealed images using (c) ZMV, (d) BMA, (e) DMVE, and (f) proposed method for FOOTBALL.

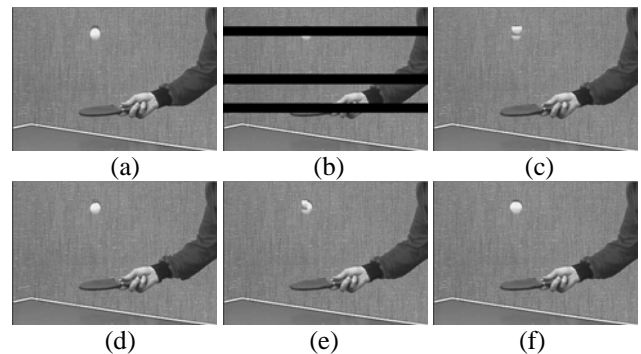


Fig. 7. (a) The original image and (b) the error image and concealed images using (c) ZMV, (d) BMA, (e) DMVE, and (f) proposed method for TABLE TENNIS.

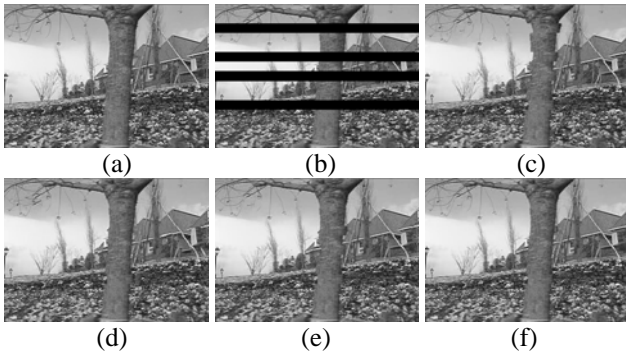


Fig. 8. (a) The original image and (b) the error image and concealed images using (c) ZMV, (d) BMA, (e) DMVE, and (f) proposed method for FLOWER GARDEN.

Table 1. The PSNR of concealed image from proposed methods and conventional methods on the MPEG-2 images.

Test images	PSNR[dB]			
	ZMV	BMA	DMVE	Proposed method
FOOTBALL	22.81	23.23	23.42	24.00
TABLE TENNIS	28.25	27.30	28.99	29.68
FLOWER GARDEN	22.38	21.76	23.81	25.05

#### 4. Conclusion

Proposed error concealment algorithm used both forward concealment and backward concealment to prevent error propagation. The proposed recursive boundary matching method improves the spatial correlation of the macroblocks (MBs) by reusing the pixels of the concealed MB and control weighting factor of the concealed MB recursively. Weighting factor means rate of block matching error in concealed region. If it uses weighting area with high rate, concealed MB will have much block error. And If it uses weighting area with low rate, that will cause blocking artifact. So proposed error concealment algorithm uses rate of weighting area with recursive method. Experimental results show that the proposed algorithm gives better results than conventional algorithms in terms of both subjective and objective image quality.

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