

Temporal Error Concealment Using the Concealed Boundary Pixels and Boundary Region Feature

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Abstract - In this paper, we proposed a temporal error concealment (EC) using the concealed boundary pixels and the adaptive block matching method. The proposed boundary matching method improves the spatial correlation of the macroblocks (MBs) by reusing the pixels of the concealed MB to estimate a motion vector of a error MB. The adaptive block matching method inspects horizontal edge and vertical edge feature of the error MB and it conceals the error MB in reference to stronger edge feature. This improves video quality by raising edge connection feature of the error MB and the neighborhood MBs. In particular, we restore a lost MB as the unit of 8×16 block or 16×8 block by using edge feature from the surrounding MBs. Experimental results show that the proposed algorithm gives better results than the conventional algorithms from a subjective and an objective viewpoint.

Keywords: concealment, boundary matching, macro-block, motion vector

1. Introduction

In the prospect of digital TV or mobile video service, coding methods such as the H.263 or the MPEG compression standards have been used to transmit the digital video signals efficiently within the limited band. Bit errors can be occurred due to interference between signals, thermal noise, and instability of the transmission system while the encoded video signals are transmitted through cables or radio.

For anchor frames (I- or P-frame), transmission errors specially 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 undecodable 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]-[5].

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 [5]. The result of this algorithm is insufficient because there is less correlation between the MBs in the neighboring frame with motion.

Lam et al. [3] 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. In addition, slanting edges and rapid gray-level change may cause a large variation in the boundary between MBs.

Zhang et al. [4] 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 and the result is better than BMA. However, like BMA, there are blocking effects in the error concealed frame and does not properly work in the regions with motion.

In this paper, we propose temporal EC algorithm using boundary region feature and adaptive block matching to compensate the image quality degradation which is occurred by block errors during video data transmission. To improve the temporal correlation between MBs, reconstructed pixels of the MB are reused as boundary pixels for concealing the corrupted MB. To conceal error with strong edge feature, adaptive block matching algorithm, which is based on the horizontal edge feature and vertical edge feature of the neighbor of the corrupted MB, is executed. Experimental results show that the proposed algorithm provides better results than conventional algorithms from both subjective and objective image quality.

2. Proposed Error Concealment Algorithm

2.1 Proposed Boundary Region Feature

To prevent blocking effects between concealed MBs, it uses the lines of pixels to the left of the lost MB which are being concealed and are shown as Fig. 1.

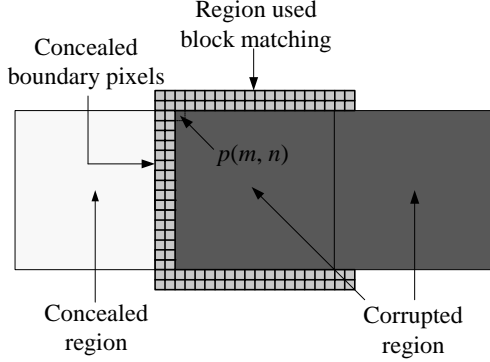


Fig. 1. Proposed boundary matching region.

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 differences of four blocks respectively. They are calculated by the following equation.

$$\begin{aligned} D_L &= \sum_{i=0}^{N-1} (\hat{p}(m, n+i) - p(m, n+i))^2 \\ D_R &= \sum_{i=0}^{N-1} (\hat{p}(m+N-1, n+i) - p(m+N-1, n+i))^2 \\ D_T &= \sum_{i=0}^{N-1} (\hat{p}(m+i, n) - p(m+i, n))^2 \\ D_B &= \sum_{i=0}^{N-1} (\hat{p}(m+i, n-N) - p(m+i, n-N))^2 \end{aligned} \quad (1)$$

In this equation, $p(m, n)$ represents the pixel intensity of the same position $p(m, n)$ in the previous frame. The summation of boundary differences D_{SUM} is

$$D = D_T + D_B + \Delta \cdot D_L \quad (2)$$

where $\Delta = \begin{cases} 1 & \text{for } R \in R_{non-error} \\ 1/2 & \text{for } R \in R_{rec} \end{cases}$

This algorithm chooses the MV from a set of candidate vectors that minimize boundary differences. The region R to compute D_L is divided into $R_{non-error}$ which has no error data and R_{rec} which is concealed due to error data.

To identify the resultant MV $V_e(x_e, y_e)$ which may be estimated properly, the distance difference L between $V_e(x_e, y_e)$ and the MV $V_l(x_l, y_l)$ that is in the left MB of the corrupted MB. That is,

$$L = \sqrt{(x_e - x_l)^2 + (y_e - y_l)^2} \quad (3)$$

If the distance difference L exceeds the threshold, the resultant MV is considered as wrong estimation and the adaptive boundary matching is used.

2.2 Complexity Calculation Considering Edge Feature

When the resultant MV is not proper, the adaptive boundary matching is used to improve the result. First, horizontal edge feature about the 8×16 block of the left boundary region in the corrupted MB is considered and vertical edge feature about the 16×8 block of the top boundary region is considered. 1st differentiation is used to extract edges because edges have large intensity differences within a region [6]. Therefore, when the edge value, summation of the number of the intensity differences which are larger than the threshold, for each boundary region of corrupted MB is large, let the horizontal and vertical edge value G and H are 0, then the adaptive boundary matching is executed.

$$G \leftarrow G + 1, \text{ if } |g_{i+1,j} - g_{i,j}| > 0 \quad (4)$$

$$H \leftarrow H + 1, \text{ if } |h_{i+1,j} - h_{i,j}| > 0 \quad (5)$$

$g_{i,j}$ represents the (i, j) th pixel intensity in the left boundary 8×16 region of the corrupted MB, and $h_{i,j}$ represents that in the top boundary 16×8 region. The horizontal edge value is large when $G \geq H$, the vertical edge value is large otherwise.

2.3 Adaptive boundary matching

Adaptive boundary matching algorithm set neighboring MVs as standard coordinates and search MBs to recover. Let a MV of the left MB of the corrupted MB is denoted by $V_l(x_l, y_l)$, and a MV of the top is denoted $V_u(x_u, y_u)$. Search coordinates are $(x_l + m, y_l + n)$, $(x_l + m, y_l + n)$, $(x_u + m, y_u + n)$ and $((x_l + x_u)/2 + m, (y_l + y_u)/2 + n)$. Horizontal and vertical edge values neighboring the corrupted MB determines a search way.

The 8×16 block restores the corrupted MB when the horizontal edge data is large and is shown as Fig. 2. The 16×8 block restores the corrupted MB when the vertical edge data is large and is shown as Fig. 3. To recover the top and bottom 16×8 block, summation of the difference within the left and top boundary, and the left and bottom boundary is calculated.

After executing one of the recovery methods for the three search region, the MB which has the smallest error value between block boundaries is replaced with the corrupted MB.

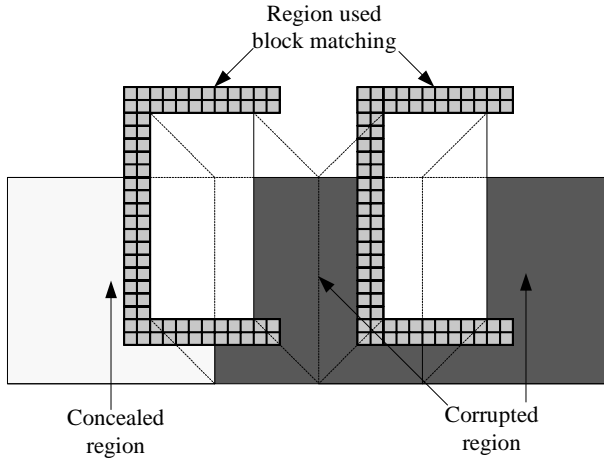


Fig. 2. Adaptive boundary matching for the dominant horizontal edge.

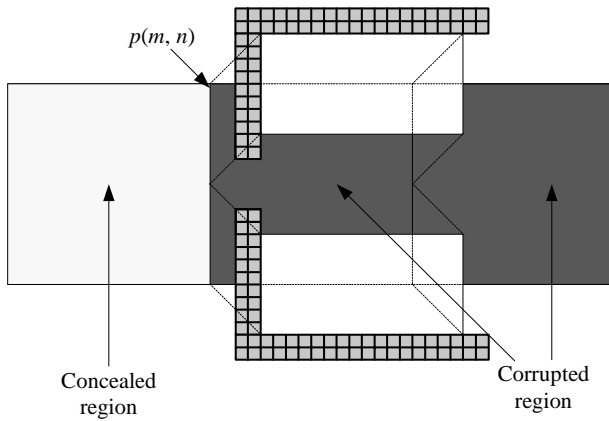


Fig. 3. Adaptive boundary matching for the dominant vertical edge.

3. Experimental Results

To test the performance of the proposed EC algorithm, computer simulations were run on four test video sequences, which are FOOTBALL, TABLE TENNIS, and FLOWER GARDEN. These video sequences are 352×240 pixels per frame. Described EC algorithms used $[-16, 16]$ search area. The PSNR of the frame reconstructed by conventional algorithms and the proposed algorithm is summarized in table 1. We observed that the proposed algorithm produces higher PSNR values than conventional algorithms. Frames reconstructed by the proposed algorithm and conventional algorithms are shown as Fig. 4. Experimental results show that the frame reconstructed by the proposed algorithm have smooth MB boundary. The proposed algorithm has better performance compared with conventional algorithms in terms of both objective and subjective image quality.

4. Conclusion

We proposed the effective EC algorithm based on the extension BMA using the concealed boundary pixels and boundary region feature. The proposed boundary matching method improves the spatial correlation of the MBs by reusing the pixels of the concealed MB to estimate a motion vector of the error MB. For the region with excessive motion, we restore a lost MB as the unit of 8×16 block or 16×8 block by using edge feature from the surrounding MBs. Experimental results show that the proposed algorithm gives better results than conventional algorithms in terms of both subjective and objective image quality.

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

Test images	PSNR [dB]			
	ZMV	BMA	DMVE	Proposed method
FOOTBALL	25.52	25.61	26.04	27.75
TABLE TENNIS	23.99	23.45	24.59	25.70
FLOWER GARDEN	28.35	28.43	29.17	30.20

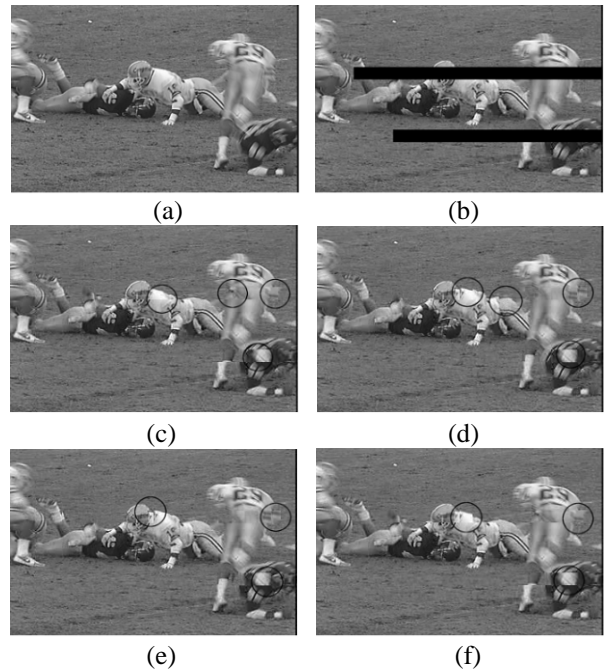


Fig. 4. (a) The original image and (b) the error image and concealed images using (c) ZMV, (d) BMA, (e) DMVE, and (f) proposed method for FOOTBALL.

5. References

- [1] Y. Wang and Q. F. Zhu, "Error control and concealment for video communication: A review," *Proc. IEEE*, vol. 8, no. 5, pp. 974-997, May 1998.
- [2] Y. Wang, Q. F. Zhu, and L. Shaw, "Maximally smooth image recovery in transform coding," *IEEE Trans. Commun.*, vol. 41, pp. 1544-1551, Oct. 1993.
- [3] W. M. Lam, A. R. Reilbman, and B. Liu, "Recovery of lost or erroneously received motion vectors," *Proc. ICASSP*, pp. V417-V420, Apr. 1993.
- [4] J. Zhang, J. F. Arnold, and M. R. Frater, "A cell-loss concealment technique for MPEG-2 coded video," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 10, no. 4, pp. 659-665, June 2000.
- [5] J. W. Suh and Y. S. Ho, "Error concealment for digital TV," *IEEE Trans.*, vol. 48, no. 4, pp. 299-306, Dec. 2002.
- [6] R. C. Gonzalez and R. E. Woods, *Digital image processing*, Addison-Wesley, New York, 1992.