Error Concealment Techniques for Digital TV

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***Abstract*—Compressed video bitstreams are intended for real-time transmission over communication networks. Most of the video coding standards employ the temporal and spatial prediction structure to reduce the transmitted video data. Therefore, the coded video bitstreams are highly sensitive to information loss and channel errors. Even a single bit error can lead to disastrous quality degradation in both time and space. This quality deterioration is exacerbated when no error resilient coding mechanism is employed to protect coded video data against the error prone environments. Error concealment is a data recovery technique that enables the decoder to conceal effects of transmission errors by predicting the lost or corrupted video data from the previously reconstructed error-free information. Motion vector recovery and motion compensation with the estimated motion vector is a good approach to conceal the corrupted macroblock data. In this paper, we develop various error concealment algorithms based on motion vector recovery, and compare their performances to those of conventional error concealment methods.**

***Index Terms*—Error concealment, motion vector estimation, MPEG-2 video codec, optical flow.**

I. Introduction

THE DIGITAL television (DTV) standard describes a system designed to transmit high quality video, audio, and ancillary data over a single 6 MHz channel. The need for video compression in a high definition television (HDTV) system is apparent from the fact that the bit rate required to represent an HDTV signal in uncompressed digital form is over 1 Gbps and the bit rate that can be transmitted reliably within a standard 6 MHz TV channel is about 20 Mbps. This implies that we need to compress HDTV signals by 50 : 1 or greater. The MPEG-2 video coding standard [1] successfully achieves high compression ratios using a hybrid algorithm of motion compensation (MC) and discrete cosine transform (DCT).

The overall flow of the DTV signal consists of several steps to transport the compressed video data from transmitter to receiver. First of all, digitized video data are compressed by a specific video coding standard adopted for a given application. The output of the encoder is segmented into fixed or variable length packets for easy transmission and multiplexed with other data types, such as audio and data. The multiplexed packets are then sent over the transmission channel after channel encoding using forward error correction codes (FEC). The received transmission packets which may include transmission errors undergo channel decoding and demultiplexing to get depacketized bitstreams. Finally, the resulting bitstreams are entered to the video decoder to reconstruct the original video.

Due to the nature of broadcasting, it is nearly impossible to design a system to be totally error free and compressed bitstreams are very sensitive to channel disturbances. Even one bit error could degrade not only the current frame but also succeeding frames. If we use mathematically well structured FEC, we can detect and correct the transmission errors. However, because FEC comparatively reduces a channel capacity, it is very difficult to correct all transmission errors. Therefore, there has been a renewal of interest in error resilience coding techniques for real-time video transmission over noisy channels, since only channel coding and decoding could not provide the perfect solution for the transmission errors [2], [3].

After channel decoding, we apply error concealment techniques for the uncorrected errors. Error concealment techniques try to recover the corrupted data by exploiting the spatial and temporal redundancies of the video data. There are mainly two different types of error concealment techniques: spatial-domain error concealment and temporal-domain error concealment. The spatial-domain error concealment algorithms interpolate the lost area using spatially neighboring image data [4]–[7]. Because these algorithms recover an isolated lost macroblock (MB) which is made by the coded modification, they provide good performances. However, if we consider the MPEG-2 video transmission for DTV, we lose successive MBs from the first erroneous MB to the beginning of the next resynchronization. Therefore, we cannot use interpolation algorithms directly and cannot expect good performances. On the other hand, temporal-domain error concealment schemes utilize previously decoded image data to recover the lost MBs [8]–[12]. In those schemes, they estimate motion vectors (MVs) for the lost MBs and compensate for the lost MBs with the estimated MVs.

In this paper, we address the problem of error concealment in packet-based transmission of the MPEG-2 coded video bitstream over a noisy channel. We especially focus on temporal-domain error concealment algorithms using the spatio–temporal redundancies in the received video signal. In order to estimate the MV of the lost MB, we use vertically neighboring MVs and luminance intensity values of the lost MB. After we review the conventional MV recovery algorithms, we propose various MV recovery schemes to improve the performance including the modified average algorithm, the extension matching algorithm with an initial MV, and the MV recovery algorithm using optical flow fields.

This paper is organized as follows. In Section II, we summarize the MPEG-2 video coding and transmission system. We then introduce an error detection algorithm used in our system. In Section III, we discuss the merits and demerits of conven-

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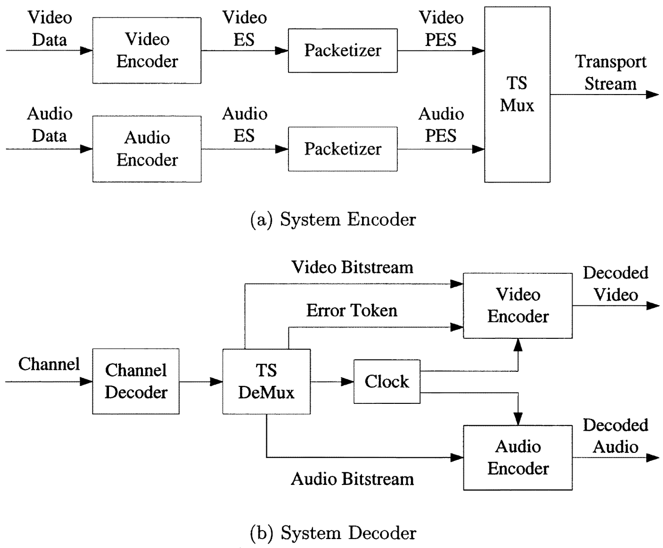


Fig. 1. MPEG-2 TS system for noisy channel.

tional temporal-domain error concealment algorithms including the average method, the boundary matching algorithm, and the decoder motion vector estimation algorithm. In order to improve the performance of error concealment operations, we propose various MV recovery schemes. Section IV presents simulation results and performance comparisons of different error concealment algorithms. Finally, we draw conclusions in Section V.

II. MPEG-2 TRANSMISSION SYSTEM

A. TS Packet Transmission

Due to the imperfect broadcasting environments, it is hard to design a completely error free DTV transmission system. As shown in Fig. 1, the MPEG-2 system standard [13] introduces a general approach which defines a transport stream (TS) packet transmission system considering noisy channels. Elementary stream (ES) is the output of each source encoder. Each ES is packetized into packetized ES (PES) before transmission. After multiplexing, TS packets are transmitted over the communication channel.

During the transmission of TS packets over the noisy channel, the TS packets may be corrupted by various noise sources. After a channel decoder detects and corrects some transmission errors, undetected bit errors within the TS packet can be indicated by the TS packet syntax. The TS packet consists of 188 bytes including 4-byte header information. The TS packet header contains a 1 bit transport-error-indicator field, which notifies whether the received TS packet has uncorrectable bit errors or not [13]. Error detection by syntax check can be notified to the source decoder in various ways. In our system, TS DeMux sends an error token to the video decoder.

If the video decoder receives a damaged packetized bitstream with an error token, there is no way to notify how many bits within the bitstream are usable. For a practical purpose, the damaged packet is thrown out and treated as a lost one. As a result, all subsequently received bitstreams become useless until synchronization is reestablished. Due to the MPEG-2 video coding algorithm, we lose horizontal MB strips from the first erroneous MB to the beginning of the next MB slice because the smallest synchronization unit is the MB slice.

B. MPEG-2 Video Coding Algorithm

Fig. 2 shows a block diagram of the MPEG-2 video codec. In order to encode I-frame, the input frame is partitioned into 8 $\times$ 8 pixel blocks. The 8 $\times$ 8 two-dimensional DCT is applied to the each block, and the DCT coefficients are quantized. Finally, the quantized DCT coefficients are entropy coded using variable length coding (VLC). In succeeding frames, temporal redundancies are removed by motion estimation (ME) and MC. Residual errors are differences between current MB and motion compensated MB. Consequently, the residual errors are coded and transmitted like the I-frame coding procedure. The MV information describing the direction and the amount of displacement of the MB is transmitted as a part of the bitstream.

Decoding is performed in the reverse order of the encoding process. If we receive the correct MV information and residual errors, we can obtain correct output pictures. However, if the video decoder receives a damaged bitstream with an error token, we cannot recover the output frame properly because we do not know the motion prediction information and the DCT coefficients of residual errors. In order to reduce effects of transmission errors, we apply error concealment in the MV Recovery block, as shown in Fig. 2.

C. Detection of Transmission Errors

Error concealment is largely dependent on the capability of error detection, since error concealment operation is applied to the corrupted MBs. As stated above, because the damaged packetized bitstream is thrown out and treated as a lost one, we can obtain the MB position of error occurrence by checking the MB address (MBA) which defines the absolute position of the MB. In our system, whenever we decode correctly received bitstreams, we store the last decoded MBA. If we receive the error token from TS DeMux, the address (recorded as MBA + 1) is the beginning position of erroneous MBs. As described earlier, since the smallest synchronization unit is the MB slice, we lose consecutive MBs until the decoder restarts a decoding procedure in the next MB slice.

III. MV RECOVERY ALGORITHMS

In this section, we describe various MV recovery algorithms. One of the difficult problems in error concealment techniques is limitation of available information. In order to conceal the lost MB, we can just use only upper and lower MBs of the lost MB considering high correlation of neighboring MBs. In addition, if the corrupted area is wider than a single MB row, the problem becomes more difficult.

The simplest method is to replace the erroneous MBs by the spatially coinciding MBs in the previous frame. It means that the lost MV is considered as zero with an assumption that no motion has occurred between the previous reference frame and the current frame. The use of zero MV produces a reasonably good approximation in small and slow motion areas. However, we cannot expect good results in large and fast motion areas.

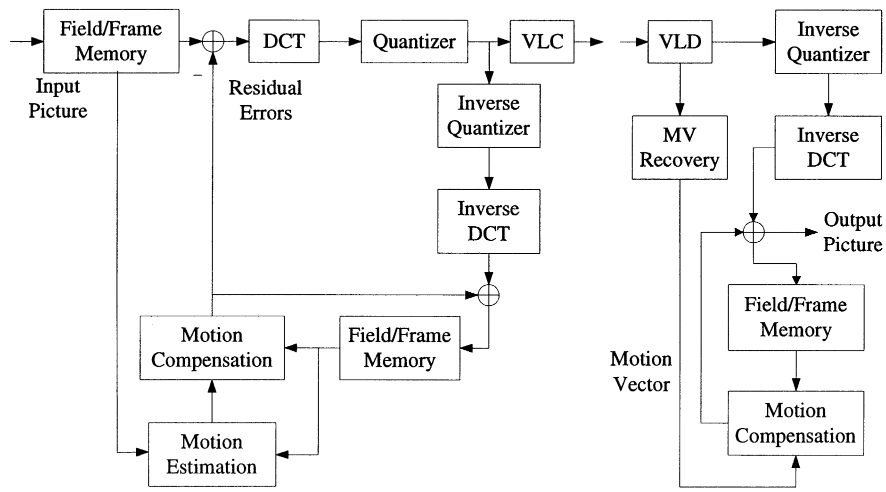


Fig. 2. Modified MPEG-2 video codec.

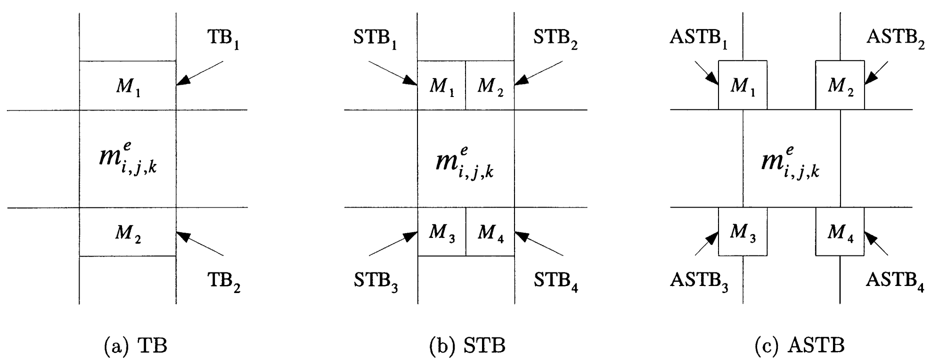


Fig. 3. Modified Average Algorithm (MAVG).

Therefore, we need different approaches to conceal the corrupted areas effectively. Estimating MVs for the lost MBs and compensating them with the estimated MVs is one way to improve performance of error concealment operations.

A. Error Concealment Using Neighboring MVs

We can exploit vertically neighboring MVs of the lost MB. MV of the lost MB can be obtained by taking the average value (AVG) of MVs of the vertically adjacent MBs [8]. In this scheme, if vertically neighboring MBs have the corresponding MVs, we can obtain reasonably good reconstruction quality of the lost MB. However, if only one or none of the vertical neighbors has a valid MV, quality of the reconstructed image is not satisfactory. Therefore, the coding mode of the adjacent MBs of the lost MB is very important to take the average value. In other words, if an adjacent intra-coded MB of the lost MB has MV, we can obtain good performances. In order to satisfy this condition, we propose a modified average algorithm (MAVG).

As shown in Fig. 3(a), after we define a 16 $\times$ 8 target block (TB) in the vertically adjacent intra MB of the lost MB, we estimate MV for the TB using the block matching algorithm. Because vertically adjacent MBs of the lost MB have MVs, we can estimate MV of the lost MB by taking average of them. In order to get a more accurate MV for the lost MB, we expand this idea further. We separate one 16 $\times$ 8 TB into two 8 $\times$ 8 small target blocks (STBs), as shown in Fig. 3(b). In this structure, the procedure to get MV of the lost MB is similar to the above algorithm.

When we compare performances of the two algorithms with that of AVG [8], we obtain slightly improved results. However, these two schemes require more computation time because they use a full search ME process. In order to reduce the computational complexity, we define an alternative small target block (ASTB) which is located in the boundary of two MBs, as shown in Fig. 3(c). With this modification, the estimated MVs, M_2 and M_4, can be used in the next MV estimation process. Therefore, we can reduce the computational complexity roughly by half.

B. Error Concealment Using Extended Boundary Pixels

Conventional MV recovery methods use boundary pixels of the lost MB to estimate the lost MV. In other words, they estimate the lost MV by noting that neighboring pixels often move together. Let the size of an image block be $N \times N$ and $E(x, y, t)$ the intensity at time t at the image point (x, y). $E_C(x, y, t)$ and $E_R(x, y, t)$ represent the motion compensated data and the residual errors, respectively. We denote the MV by m, and its x, y components by m_x and m_y, respectively. The reconstructed pixel value is represented by

$$\begin{aligned} E(x, y, t) &= E_C(x, y, t) + E_R(x, y, t) \\ &= E(x + m_x, y + m_y, t - 1) + E_R(x, y, t). \end{aligned} \tag{1}$$

Because we cannot obtain the MV information and the data of residual errors in corrupted areas, a concealed image block with the estimated MV can be expressed as

$$\hat{E}(x, y, t) = E(x + m_x^e, y + m_y^e, t - 1) \quad x_1 \le x < x_N \text{ and } y_1 \le y < y_N \tag{2}$$

where m_x^e and m_y^e are the estimated MV components in the x and y directions, respectively. (x_1, y_1) is the most upper and left coordinate of the image block.

The boundary matching algorithm (BMA) [9] uses one pixel boundary line of the above, below, and left of the lost MB to estimate MV of the lost MB. Firstly, we define B_A, B_B, and B_L by

$$\begin{aligned} B_A &= \sum_{x=x_1}^{x_N} \left(E(x, y_1, t-1)|_{x,y\in SR} - E(x, y_1 - 1, t)\right)^2 \\ B_B &= \sum_{x=x_1}^{x_N} \left(E(x, y_N, t-1)|_{x,y\in SR} - E(x, y_N + 1, t)\right)^2 \\ B_L &= \sum_{y=y_1}^{y_N} \left(E(x_1, y, t-1)|_{x,y\in SR} - E(x_1 - 1, y, t)\right)^2. \end{aligned} \tag{3}$$

Equation (3) is the squared sum of differences (SSD) between the outer one pixel boundary line of the above, below, and left sides of the lost MB in the current frame and the outmost boundary pixels of the target block in the previous reference frame. Values of B_A, B_B, and B_L are calculated within the search range (SR). BMA chooses the MV of the lost MB among a set of candidate MVs which produces the smallest total difference $B = B_A + B_B + B_L$.

The decoder motion vector estimation algorithm (DMVE) [12] is similar to BMA; however, DMVE uses outer several pixel boundary lines (one to eight) of the lost MB in the current frame and the previous reference frame to calculate SSD

$$\begin{aligned} D_A &= \sum_{y=y_1-k}^{y_1-1} \sum_{x=x_1}^{x_N} \left(E(x, y, t-1)|_{x,y\in SR} - E(x, y, t)\right)^2 \\ D_B &= \sum_{y=y_N+1}^{y_N+k} \sum_{x=x_1}^{x_N} \left(E(x, y, t-1)|_{x,y\in SR} - E(x, y, t)\right)^2 \\ D_L &= \sum_{x=x_1-k}^{x_1-1} \sum_{y=y_1}^{y_N} \left(E(x, y, t-1)|_{x,y\in SR} - E(x, y, t)\right)^2. \end{aligned} \tag{4}$$

DMVE chooses the MV of the lost MB among a set of candidate MVs which produces the smallest total difference $D = D_A + D_B + D_L$. In this algorithm, a boundary pixel width k and the size of SR are very important parameters in the ME process of the lost MB. If the value of k and the size of SR are increased, the computational time will be increased. Therefore, this algorithm entails a considerable amount of processing complexity compared to BMA.

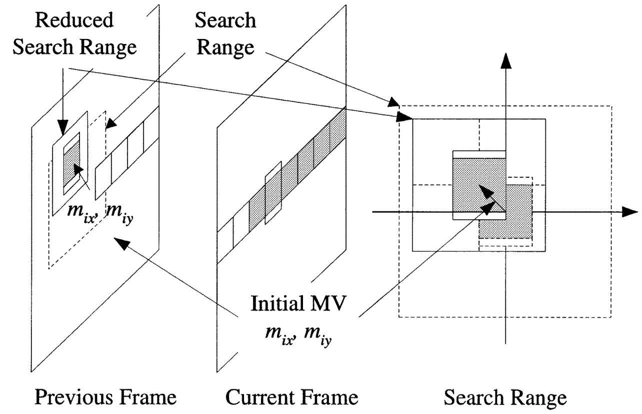


Fig. 4. EMA with Initial Motion Vector (IEMA).

However, these two algorithms have significant limitations. When video data are received with transmission errors, left pixels of the lost MB are not available for calculating B_L and D_L. As described earlier, if an error corrupts a particular MB, the decoder fails to reconstruct forthcoming MBs correctly until synchronization is reestablished. Nevertheless, if left pixels are used for SSD, the MV estimation process already includes the error concealment mismatch. In addition, they require high computation time due to the ME process with the extended pixels at the decoder. To resolve these problems, we propose an extension matching algorithm with an initial MV (IEMA).

In order to reduce the computational complexity, we use an initial MV [11], as shown in Fig. 4. First, we set the initial MV for the lost MB by AVG [8] and calculate SSD of the above and bottom boundary pixels like (5). The initial MV (m_{ix}, m_{iy}) establishes a starting point of SR, and it enables the ME process to reduce SR. If none of the vertical neighbors has a valid MV, we use the default SR

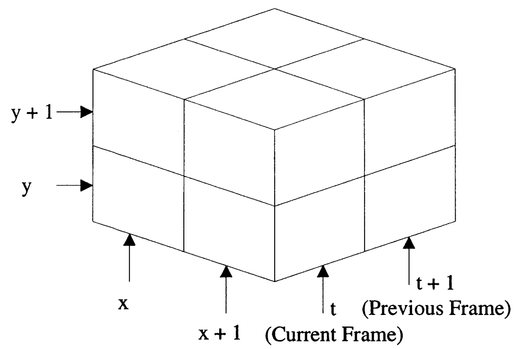
$$\begin{aligned} E_A &= \sum_{y=y_1-k}^{y_1-1} \sum_{x=x_1}^{x_N} \left(E(x + m_{ix}, y + m_{iy}, t-1)|_{x,y\in RSR} \right. \\ &\qquad \left. - E(x, y, t)\right)^2 \\ E_B &= \sum_{y=y_N+1}^{y_N+k} \sum_{x=x_1}^{x_N} \left(E(x + m_{ix}, y + m_{iy}, t-1)|_{x,y\in RSR} \right. \\ &\qquad \left. - E(x, y, t)\right)^2 \end{aligned} \tag{5}$$

where RSR represents the reduced search range.

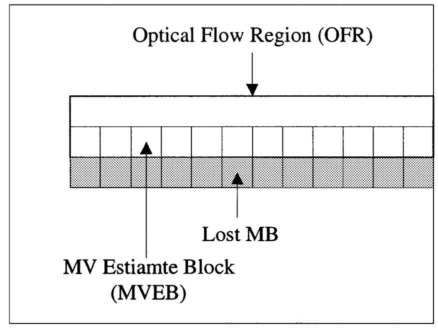
IEMA demonstrates improved performance compared to those of the other algorithms. However, if the corrupted areas are wider than a single row of MBs, it does not work well. It means that we cannot use both E_A and E_B in the ME process of the lost MB because successive slice errors have occurred. In order to resolve this problem, we propose MV recovery algorithm using optical flow fields.

C. Error Concealment Using Optical Flow Fields

Optical flow is the distribution of apparent velocities of movement of brightness patterns in the image. Optical flow is very similar to the true motion because optical flow arises from relative motion of the objects and the viewer. In order to obtain op-



(a) Space and Time



(b) Optical Flow Fields

Fig. 5. MV recovery using optical flow.

tical flow fields, we use a simple algorithm proposed by Horn and Schunch [15]. To determine the optical flow fields, we need to solve the double integral composed of optical flow constraint and the smoothness constraint

$$\epsilon = \iint \left[(E_x u + E_y v + E_t)^2 + \alpha^2 \left(u_x^2 + u_y^2 + v_x^2 + v_y^2 \right) \right] \, dx \, dy \tag{6}$$

where u and v are the x and y components of the optical flow fields, E_x, E_y, and E_t means partial derivatives of image brightness with respect to x, y and t, respectively. The minimization is accomplished by finding suitable values for the optical flow velocity (u, v). Using a calculus of variation method and an approximation of Laplacian, we can have

$$\begin{aligned} \left(\alpha^2 + E_x^2 + E_y^2\right)(u - \overline{u}) &= -E_x(E_x\overline{u} + E_y\overline{v} + E_t), \\ \left(\alpha^2 + E_x^2 + E_y^2\right)(v - \overline{v}) &= -E_y(E_x\overline{u} + E_y\overline{v} + E_t). \end{aligned} \tag{7}$$

The term α^2 plays a significant role only for areas where the brightness gradient is small, preventing haphazard adjustments to the estimated flow velocity occasioned by noise in the estimated derivatives. Optical flow fields can be computed by a new set of velocity estimates (u^{n+1}, v^{n+1}) from the estimated derivatives and the average of the previous velocity estimates (u^n, v^n) as (8)

$$\begin{aligned} u^{n+1} &= \overline{u}^n - E_x \left(E_x \overline{u}^n + E_y \overline{v}^n + E_t \right) / \left(\alpha^2 + E_x^2 + E_y^2 \right), \\ v^{n+1} &= \overline{v}^n - E_y \left(E_x \overline{u}^n + E_y \overline{v}^n + E_t \right) / \left(\alpha^2 + E_x^2 + E_y^2 \right) \end{aligned} \tag{8}$$

where n is the iteration number, and $\overline{u}$ and $\overline{v}$ are the local average values of velocity [15].

In order to recover MV of the lost MB, we can use the optical flow fields of correctly decoded neighboring MB data. As shown in Fig. 5(b), we obtain optical flow fields of the optical flow region (OFR) by (8). The relationship of space and time to obtain partial derivatives is shown in Fig. 5(a). It means that the calculation of optical flow fields computations are based on only two frames: the current frame and the previous reference frame. Then, we take average of optical flow fields within the MV estimate block (MVEB) that comes in touch with the lost MB. The average value is used as MV of the lost MB. In this algorithm, although two successive MB slice data are lost, we can obtain relatively well estimated MVs of the lost MBs. MVs of the first MB row of the corrupted areas can be estimated using OFR at the top region of the lost MBs and the second row can be obtained at the bottom region of the lost MBs.

IV. Simulation Results

In order to evaluate the performance of the error concealment algorithms, five different 4 : 2 : 0 CCIR 601 test sequences have been used: FOOTBALL, BICYCLE, BALLET, FLOWER GARDEN, and TRAIN. They have been coded by the MPEG-2 encoder at 5 Mbps at 30 frames/sec. We use the restricted slice structure, $N = 12$ (the number of frames in a GOP), and $M = 3$ (the number of frames between successive I- and P- or P- and P-frames). The GOP structure implies that if some errors occur in the I-frame, the effects of data corruption propagate through all other frames within GOP including the corrupted frame. Similarly, an error of the P-frame may affect neighboring P-frames and B-frames, while errors of the B-frame can be isolated. Therefore, it is desirable to develop error concealment algorithms for reference frame to prevent error propagation. In this paper, we lose one TS packet in the first P-frame, and conceal the corrupted MBs using the several error concealment algorithms.

Computer simulations have been performed to compare described temporal-domain error concealment algorithms: three conventional algorithms which include AVG [8], BMA [9], and DMVE [12] and the proposed algorithms including MAVG, IEMA, and OFA. In order to estimate MV of the lost MB, every MV recovery algorithm uses [−25, 24] SR with a full search algorithm which is called a block matching algorithm. While BMA takes one pixel boundary line, DMVE can exploit variable pixel boundary lines from one to eight. From the simulation, we found that DMVE produces the best results when it takes two pixel boundary lines. MAVG uses the ASTB structure to reduce computation time and the size of STB is 8×8. IEMA produces the best performance when we take one pixel boundary line. In addition, it has [−5, 4] reduced SR and [−25, 24] normal SR. In OFA, because the width of OFR is 32 pixels, the iteration number n is 32. α equal to 1 and the size of MVEB is the same as that of MB.

TABLE I
PSNR VALUES OF VARIOUS MV RECOVERY ALGORITHMS

	FOOTBALL	BICYCLE	BALLET	FLOWER GARDEN	TRAIN
Original	32.59	26.57	29.12	26.36	24.88
AVG	30.62	24.55	28.41	24.90	22.95
MAVG	31.50	25.05	28.76	24.50	23.00
BMA	31.25	23.37	28.53	25.11	23.39
	31.17	23.14	28.50	25.00	23.36
DMVE	31.23	23.30	28.52	25.12	23.38
	31.15	23.11	28.31	24.93	23.00
IEMA	32.21	25.42	29.01	25.04	23.44
	31.65	25.24	28.82	25.00	23.15
OFA	31.75	25.21	28.87	25.36	23.14

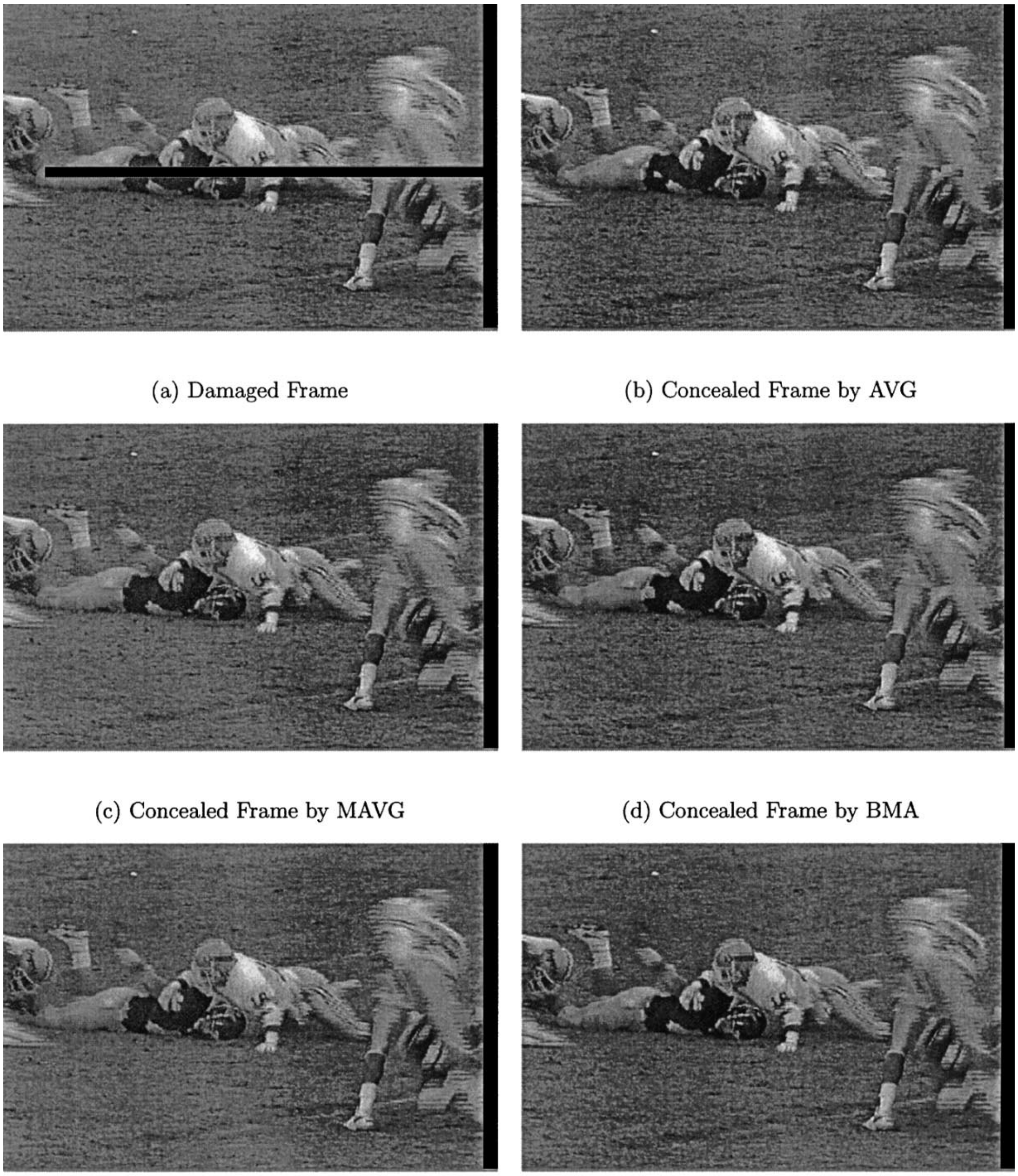
TABLE II
COMPARISON OF COMPUTATIONAL COMPLEXITY

	(-) operation	(+) operation	($\times$) operation
BMA	$50\times50\times16\times3$	$50\times50\times15\times3$	$50\times50\times16\times3$
	$= 120000$	$= 112500$	$= 120000$
DMVE	$50\times50\times16\times3\times2$	$50\times50\times15\times3\times2$	$50\times50\times16\times3\times2$
	$= 240000$	$= 225000$	$= 240000$
IEMA$_{worst}$	$50\times50\times16\times2$	$50\times50\times15\times2$	$50\times50\times16\times2$
	$= 80000$	$= 75000$	$= 80000$
IEMA$_{best}$	$10\times10\times16\times2$	$10\times10\times15\times2$	$10\times10\times16\times2$
	$= 3200$	$= 3000$	$= 3200$
OFA	$32\times16\times3\times4$	$32\times16\times3+32\times16\times4$	$32\times16\times3\times3+32\times16\times3\times12$
	$+32\times2$	$+32\times6\times2$	$+32\times4\times2$
	$= 6208$	$= 23296$	$= 3968$

Table I summarizes the peak-signal-to-noise ratio (PSNR) of the reconstructed P-frames for the five test sequences. BMA and DMVE demonstrate similar performances. We also observe that IEMA produces higher PSNR values than any other methods. If objects have mixed displacements, as in FOOTBALL and BALLET, BMA produces relatively good results. However, if objects have uniform displacements, as in BICYCLE, FLOWER GARDEN, and TRAIN, AVG shows comparatively good performance. Because IEMA takes the advantages of AVG and BMA, it provides the highest PSNR values. In addition, OFA yields good performance when we cannot use the bottom boundary pixels of the lost MBs as shown in the second row of each algorithm.

Table II compares the computational complexity of different error concealment algorithms. We count the numbers of $(-)$, $(+)$, and $(\times)$ operations to estimate MV of the lost MB. In the case of BMA, we need 120 000 $(-)$ and $(\times)$ operations and 112 500 $(+)$ operations to determine the smallest SSD except for a sorting operation. In the case of OFA, we have to calculate partial derivatives just one time. In addition, we calculate local averages $\overline{u}$ and $\overline{v}$ and temporary velocity estimates u^n and v^n in each iteration, respectively. IEMA$_{worst}$ means that we cannot use the initial MV and use the default SR. IEMA$_{best}$ is obtained using the reduced SR. While MV recovery methods based on motion estimation with the full search algorithm have a big burden on computation time, OFA requires few iterations to obtain the optical flow in OFR.

When we compare performances of error concealment algorithms, we need to test the subjective picture quality of reconstructed frames. Fig. 6 shows concealed P-frames obtained by various error concealment algorithms with the FOOTBALL sequence. The results clearly show that reconstructed P-frames by IEMA and OFA have smooth MB boundaries. With other test sequences, we obtain good results using IEMA and OFA. For the BALLET sequence, it is hard to recover the corrupted MBs because the MB size is relatively large to represent the cloth of both ballet dancers. In the case of a slow motion scene, such as FLOWER GARDEN and BICYCLE, we see that OFA produces the best subjective quality than other algorithms. From the objective and subjective quality test, we have observed that IEMA provides the best results. However, if the corrupted areas are wider than one MB row, OFA generates the good results.



(a) Damaged Frame
(b) Concealed Frame by AVG
(c) Concealed Frame by MAVG
(d) Concealed Frame by BMA
(e) Concealed Frame by IEMA
(f) Concealed Frame by OFA

Fig. 6. Subjective quality comparison.

V. Conclusions

In this paper, we have proposed various error concealment techniques for digital television application. Since MPEG-2 video compressed bitstreams are very sensitive to transmission errors, we need a mechanism to mitigate effects of transmission errors on the decoded picture quality. Error concealment algorithms attempt to reduce the visual degradation in the reconstructed video sequence. In this paper, we have reviewed merits and demerits of the conventional MV recovery algorithms, and proposed new MV recovery algorithms to improve the performance of error concealment operations. Simulation results demonstrate that IEMA has better results than any other methods. However, if corrupted areas are wider than a single row of MBs, OFA produces good performances.

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