Error Concealment Scheme for H.263 Coded Video Transmissions

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Abstract

A new error concealment method is proposed that uses motion estimation considering actual motions in moving pictures. Since many videos include a variety of complex 3-D motions, such as rotation, magnification, reduction, and parallel motion, the proposed error concealment method uses an affine transform, which divides lost macroblocks into triangular patches and then considers six motion parameters to produce accurate motion estimations for videos including complex motions. When compared to conventional error concealment methods that only handle parallel motions, the proposed method is able to estimate the motion of lost data more accurately, thereby producing a higher PSNR value and better subjective video quality.

1. Introduction

Most video coding algorithms utilize motion compensation to exploit the temporal redundancy of the video information being sent, along with various mathematical transforms, such as a discrete cosine transform (DCT), to reduce the spatial redundancy. Other video services, like video conferencing and video telephony, require a higher compression ratio for a low bit rate transmission. One such compression method is ITU-T H.263,[1] which is a hybrid scheme of inter-picture prediction that utilizes the temporal redundancy and transform coding of the remaining signal to reduce the spatial redundancy. Variable length coding is used for the symbols that are transmitted.

In H.263 video, the basic synchronization unit is a group of blocks (GOB), so when a macroblock is corrupted, the succeeding elements in the same GOB are also discarded. In addition, any errors that are generated in the channels and networks also distort the video quality and are propagated in both the spatial and temporal domains. Forward error correction (FEC) can lead to a prohibitive amount of overhead and closed-loop error control techniques, like repeat on request (ARQ), also resulting in an intolerable delay. In this case, the video decoder has to try and hide the visual degradation as well as possible.

In an attempt to solve these problems, a number of error concealment techniques[2]~[9] have been previously developed, most of which apply block matching to motion estimation. However, since all these methods only consider simple parallel motion, they are unable to produce good results with videos that include complex motions, like rotation, magnification, and reduction.

Accordingly, this Letter proposes the application of an affine transform to error concealment to improve the video quality. The estimation of a lost data block is performed using an affine transform with six parameters, which are obtained by using a neighboring block with no lost data.

2. Conventional Error Concealment Methods

In motion compensated video coding like H.263 or MPEG, lost or erroneously received video data not only corrupts the current frame, but also propagates errors to succeeding frames. This error propagation, in both spatial and temporal directions, then results in a serious visual distortion of the output video.

Various error concealment methods have been proposed to decrease the effect of error propagation. One of these is to substitute a zero motion vector for a lost one. Since this method assumes less motion between consecutive frames, the use of a zero motion vector produces a good performance for background or still images. However, the same result cannot be expected with moving images that include relatively fast motion. Other methods use the motion vector of the same block in the previous frame or the median or average motion vectors of the available neighboring blocks. Yet these methods are inappropriate for an image that includes different motions among the neighboring blocks of the lost block.

Another conventional error concealment method uses a boundary matching algorithm (BMA),[2],[3] which estimates a lost motion vector using the spatial correlation between the boundary pixels of the lost block and the boundary pixels of the available neighboring ones. This method first determines the variations between the current image block and the one above it, the one to its left, and the one below it, respectively, and then selects the motion vector with the smallest total variation in this three-block boundary within the search range. In this case, the chosen motion vector is regarded as the optimal motion vector of the lost block. However, there is still a degradation in image quality when the lost block contains diagonal edges at the boundary.

Consequently, even though a series of modified boundary matching algorithms have also been developed over the last few years, none of the conventional error concealment methods mentioned above can produce effective results for a lost block that includes complex 3-D motions, such as rotation, magnification, and reduction.

3. Affine Transform

Geometric transformation models applicable to a list of match points from two images can be used to establish an affine transform that is a good approximation of the perspective geometry. An affine transform pertains to a mathematical transformation of coordinates that is equivalent to a translation, rotation, expansion, or contraction with different x and y directions in relation to a fixed origin and fixed coordinate system.

Transformation equations that include complex 3-D motions can be expressed as

$$\begin{aligned} x' &= (x\cos\theta + y\sin\theta)S_x + T_x \qquad (1)\\ &= (S_x\cos\theta)x + (S_x\sin\theta)y + T_x\\ y' &= (-x\sin\theta + y\cos\theta)S_y + T_y\\ &= (-S_y\sin\theta)y + (S_y\cos\theta)y + T_y \end{aligned}$$

where, x and y are the input pixel coordinates, x' and y' are the output pixel coordinates, T_x and T_y represent shifting along the x and y axes, respectively, S_x and S_y represent scaling along the x and y axes, respectively, and θ represents the rotation angle.

By substituting coefficients a_1, a_2, a_3, a_4, a_5, and a_6 for $S_x\cos\theta$, $S_x\sin\theta$, T_x, $-S_y\sin\theta$, $S_y\cos\theta$, and T_y, the generalized forms can be given by

$$\begin{aligned} x' &= a_1x + a_2y + a_3 \qquad (2)\\ y' &= a_4x + a_5y + a_6 \end{aligned}$$

4. The Proposed Algorithm

The proposed error concealment method uses an affine transform, which divides lost macroblocks into triangular patches

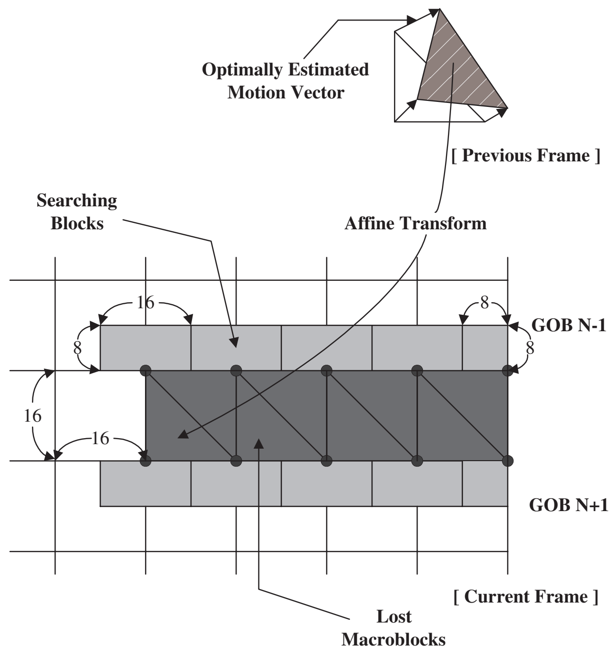

Figure 1: *Error concealment method using affine transform.*

and then considers six motion parameters to produce accurate motion estimations for videos including complex motions. This method also uses correctly decoded neighboring block data as searching blocks, as shown in Fig. 1.

Motion estimations of the respective vertexes of the triangular patches are performed using a block matching algorithm that can exploit these uniformly sized searching blocks. The corresponding vertex coordinates of the triangular patches in the previous frame are determined using optimal motion vectors. The affine transform is expressed in eqn. (2) and its parameters, a_1 to a_6 in eqn. (3) and (4), are obtained based on the pixel coordinates of the corresponding triangular vertexes.

$$\begin{pmatrix} x_1' & x_2' & x_3' \\ y_1' & y_2' & y_3' \end{pmatrix} = \begin{pmatrix} a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 \end{pmatrix} \begin{pmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ 1 & 1 & 1 \end{pmatrix} \qquad (3)$$

$$\begin{pmatrix} a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 \end{pmatrix} = \begin{pmatrix} x_1' & x_2' & x_3' \\ y_1' & y_2' & y_3' \end{pmatrix} \begin{pmatrix} x_1 & x_2 & x_3 \\ y_1 & y_2 & y_3 \\ 1 & 1 & 1 \end{pmatrix}^{-1} \qquad (4)$$

where, x_1, x_2, x_3 and y_1, y_2, y_3 are the pixel coordinates of the triangular vertexes in the current frame, and x_1', x_2', x_3' and y_1', y_2', y_3' are the pixel coordinates of the triangular vertexes in the previous frame.

Eqn. (2) and the parameters a_1 to a_6, as obtained above, can then be used to predict the locations in the previous frame that correspond to the internal pixels of triangular patches in the current frame.

In motion compensation, the intensity of the estimated

Table 1. PSNR comparison relative to error concealment methods.

Image / Method	Carphone		Susie	
	PSNR [dB]		PSNR [dB]	
	60th decoded image	61th decoded image	19th decoded image	20th decoded image
No Loss	34.73	34.63	37.30	37.08
Loss	12.18	13.73	13.53	14.16
Zero MV	27.32	28.47	27.48	28.14
Avg. MV	28.40	29.36	30.90	31.69
BMA	25.13	24.43	31.29	32.23
Proposed	30.33	31.24	31.84	32.42

locations, $\tilde{I}_{n-1}(x',y')$, can be calculated using a bilinear interpolation as follows:

$$\begin{aligned}\tilde{I}_{n-1}(x',y') = \quad & (1-\alpha)(1-\beta)\tilde{I}_{n-1}(X,Y) \\ & +(1-\alpha)\beta\tilde{I}_{n-1}(X,Y+1) \\ & +\alpha(1-\beta)\tilde{I}_{n-1}(X+1,Y) \\ & +\alpha\beta\tilde{I}_{n-1}(X+1,Y+1)\end{aligned} \quad (5)$$

where, (X,Y) and (α,β) are the integer and decimal part of the estimated pixel coordinates, (x',y'), respectively. The intensity values calculated from eqn. (5) are then used to reconstruct the lost blocks, thereby producing the proposed error concealment.

5. Simulations

A variety of conventional error concealment methods and the proposed method were applied to the video sequences Carphone and Susie, which contain complex 3-D motions. Both videos were in a QCIF format 176×144 pixels/frame and were encoded using the pattern of IPPP$\cdots$ at a frame rate of 10 frames/sec. A comparison of the effects of error concealment was made between conventional methods, including the utilization of a zero motion vector (Zero MV), an average motion vector of the available upper and lower blocks (Avg. MV), and a Boundary Matching Algorithm (BMA), and the proposed method (Proposed).

Table 1 compares the peak signal-to-noise ratio (PSNR) of the two test sequences based on the different error concealment methods. It is clear that the proposed method produced the best PSNR when compared with the conventional methods. Furthermore, because the sequence Carphone has a more complex background and faster motions than the sequence Susie, the result for Carphone was better. Fig. 2 also shows that the proposed error concealment method efficiently decreased the error propagation in the time domain. Fig. 3 illustrates a better subjective video quality in the sequence Carphone when using the proposed method, especially with regard to the hand rotation and diagonal section of the window frame where BMA showed a weakness.

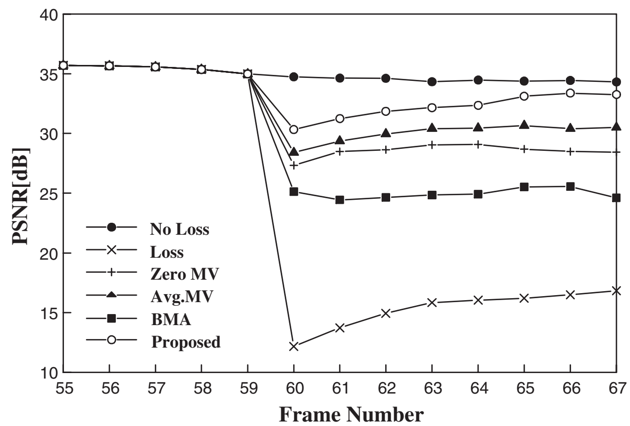

Figure 2: *Error propagation comparison of Carphone concealed by conventional methods and proposed method.*

When complex motions, such as the rotation, magnification, and reduction of image frames, are lost, the proposed method can produce a higher PSNR and better subjective video quality.

6. Conclusion

An error concealment method using an affine transform was proposed for videos that include complex motions like rotation, magnification, and reduction. It divides lost macroblocks into triangular patches and then considers six motion parameters to produce accurate motion estimations. Experimental results show that the proposed error concealment method can produce a higher PSNR value and better subjective video quality when compared to conventional methods.

7. References

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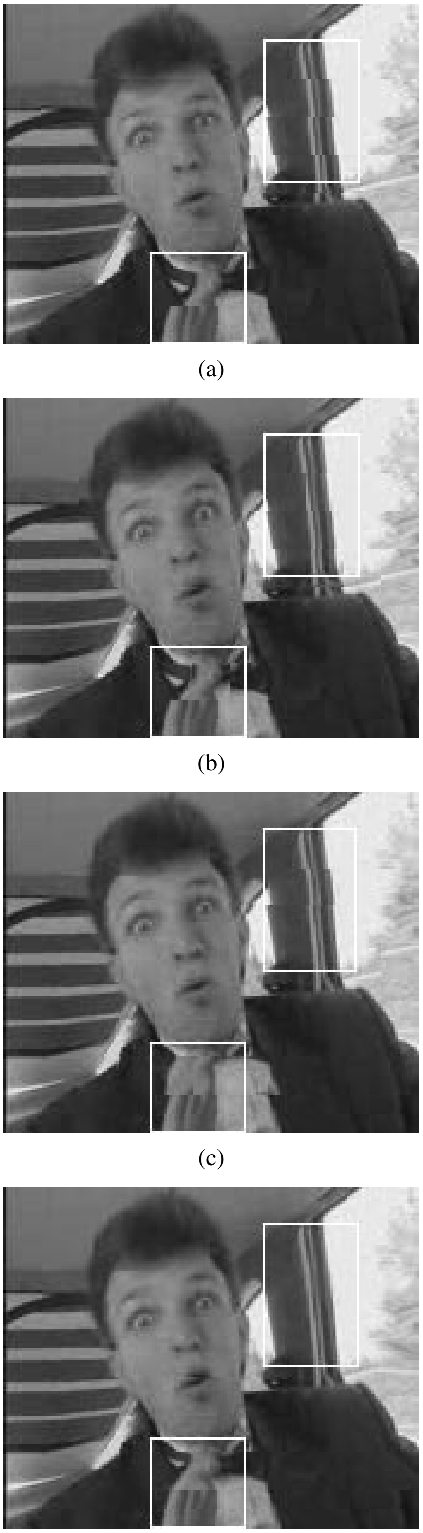

(a)

(b)

(c)

(d)

Figure 3: *Subjective image quality comparison of Carphone concealed by conventional methods and proposed method (a) Zero MV (b) Ave. MV (c) BMA (d) Proposed error concealment method.*

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