ERROR CONCEALMENT IN MPEG-4

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ABSTRACT

The paper presents an implementation of an error concealment technique for corrupted MPEG-4 video bitstreams. The proposed technique focuses on a reconstruction of corrupted I-frames using the remaining frequency domain information. The DC and AC coefficients of the missing block are estimated using information from the neighbouring block. The technique described produces better PSNR values for many sequences than published techniques

1. INTRODUCTION

Compressed video is known to be very sensitive to errors. The rapid growth in communication technologies has produced many requirements for the transmission of compressed video over error-prone/lossy networks. The MPEG-4 standard is designed to assist in these requirements by including in the standard some optional error resilience tools such as Video Packets, Data Partitioning and Reversible Variable Length Codes in order to minimise the effects from transmission errors. In spite of these error resilience tools, errors are still introduced in the decoded bitstream and cause degradation in visual quality. Hence, error concealment techniques are needed to conceal the remaining errors in the decoded images.

In this paper, we propose a spatial error concealment technique for MPEG-4 I-frames. The proposed technique reconstructs the corrupted blocks based on DC and AC coefficients estimated from the neighbour blocks. The DC coefficients estimation is based on linear weight coefficients while the AC coefficients estimation can be estimated using a combination of AC coefficients estimation/prediction from [4] and [7]. In order to fulfil the MPEG-4 stream specification [1], the technique is designed to apply to macroblocks of size 16x16 rather than 8x8. It is also able to cope with burst errors in consecutive blocks.

2. PROPOSED TECHNIQUE

2.1. DC Estimation

The DC coefficient of a missing block can be estimated using the neighbouring blocks on the left, top-left, top and top-right [2]. The DC coefficient of the missing block, *dc*, can be estimated using the following linear equation:

$$dc = dc_L w_L + dc_{TL} w_{TL} + dc_T w_T + dc_{TR} w_{TR} \quad (1)$$

where dc_L, dc_{TL}, dc_T, dc_{TR} and w_L, w_{TL}, w_T, w_{TR} are the DC coefficients and linear weight of the left, top-left, top and top-right block respectively. The DC coefficient of the missing block is shown in Figure 1.

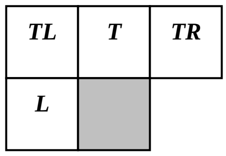


Figure1. Missing Block and its surrounding neighbours for DC weight estimation

To obtain a set of linear weight coefficients, 20 training frames from each video sequence have been chosen. Those video sequences are foreman, football, bus, table tennis, mobile, enterprise and garden. The linear weight coefficients of the DC estimator can be calculated using Linear Least Square (LLS). Since the number of training equations is more than the linear weight coefficients, the weight coefficients can be obtained from Overdetermined Linear Least Square (OLLS) as [3]:

$$w_{xi} = \left(dc_{xi}^T dc_{xi}\right)^{-1} dc_{xi}^T dc_i \quad (2)$$

where

$$dc_{xi} = \begin{bmatrix} dc_{L1} + dc_{TL1} + dc_{T1} + dc_{TR1} \\ dc_{L2} + dc_{TL2} + dc_{T2} + dc_{TR2} \\ dc_{L3} + dc_{TL3} + dc_{T3} + dc_{TR3} \\ \vdots \\ dc_{Li} + dc_{TLi} + dc_{Ti} + dc_{TRu} \end{bmatrix} \quad (3)$$

and

$$dc_i = \begin{bmatrix} dc_1 \\ dc_2 \\ dc_3 \\ \vdots \\ dc_i \end{bmatrix} \quad (4)$$

The linear weight coefficients for the left, top-left, top and top-right block obtained from the OLLS are 0.8359, -0.5960, 0.6994 and 0.0614 respectively.

If any neighbouring blocks do not exist for a specific missing block, the weight coefficient with regard to the neighbouring block will be set to zero (e.g. if the missing block is located on the first column, the weight coefficient of left and top-left will be set to zero).

2.2 AC Estimation

Firstly, the first five AC coefficients in the missing block can be estimated using DC coefficients in the eight surrounding blocks as mentioned in [4] – [6]. Figure 2 shows the surrounding neighbours that are used in the first five AC coefficients estimation. The AC coefficients can be estimated using

DC1	*DC2*	*DC3*
DC4	*DC5*	*DC6*
DC7	*DC8*	*DC9*

Figure2. Surrounding neighbourhood blocks that are used in the first five AC coefficients estimation.

$$\begin{aligned} AC(0,1) &= 1.13884(DC_4 - DC_6) \div 8 \\ AC(1,0) &= 1.13884(DC_2 - DC_8) \div 8 \\ AC(2,0) &= 0.27881(DC_2 + DC_8 - 2DC_5) \div 8 \\ AC(1,1) &= 0.16213(DC_1 + DC_9 - DC_3 - DC_7) \div 8 \\ AC(0,2) &= 0.27881(DC_4 + DC_6 - 2DC_5) \div 8 \end{aligned} \quad (5)$$

where $AC(0,1)$, $AC(1,0)$, $AC(2,0)$, $AC(1,1)$ and $AC(0,2)$ are the AC coefficients in the first to the fifth rank in zigzag scan order.

If the missing block is located at the edge, the DC coefficients of the surrounding blocks that are outside the boundary will be replaced by the DC coefficient of the centre block. For example, if the missing block is at the first column but is not in the first and last row, the equation in (5) will be rewritten as:

$$\begin{aligned} AC(0,1) &= 1.13884(DC_5 - DC_6) \div 8 \\ AC(1,0) &= 1.13884(DC_2 - DC_8) \div 8 \\ AC(2,0) &= 0.27881(DC_2 + DC_8 - 2DC_5) \div 8 \\ AC(1,1) &= 0.16213(DC_9 - DC_3) \div 8 \\ AC(0,2) &= 0.27881(DC_6 - DC_5) \div 8 \end{aligned} \quad (6)$$

After, the first five AC coefficients have been estimated, either the remaining AC coefficients in the first column or the first row will be predicted based on the directional gradients. The gradients are calculated as shown in [7]:

$$\begin{aligned} G_x &= \|DC_2 - DC_1\| \\ G_y &= \|DC_4 - DC_1\| \end{aligned} \quad (7)$$

Therefore, the remaining AC coefficients can be predicted as:

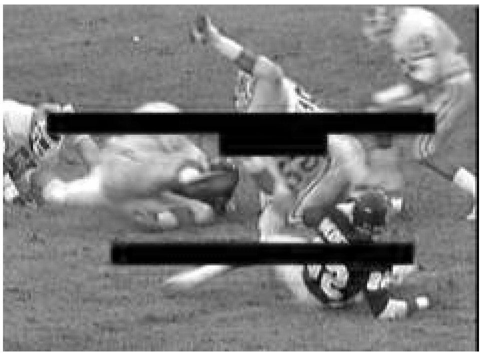
$$AC_{PRED} = \begin{cases} AC2_{1,N} & if\ G_x > G_y \\ AC4_{M,1} & if\ G_y > G_x \end{cases} \quad (8)$$

where *AC2*, *AC4* are AC coefficients in the top and left block, and, *M* and *N* are row and column numbers in the range 4 to MB size respectively.

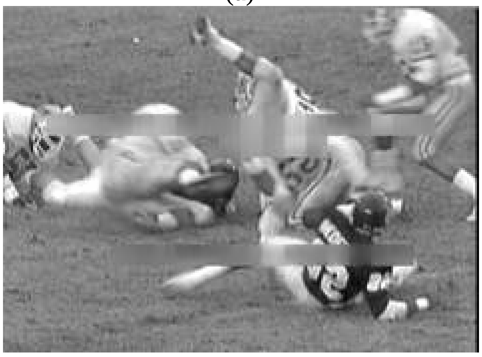
3. EXPERIMENTAL RESULTS

The DC and AC estimation techniques are applied to the corrupted I-frames based on a macroblock size of 16x16. The technique is applied on both luminance (Y-plane) and chrominance (C_b and C_r plane) planes. Since the estimation of the first five AC coefficients requires information from the blocks in the error propagation direction (DC6 – DC9), the estimator requires 2 scans in order to avoid the AC estimation taking the fault DC coefficient into account. The first scan is for DC estimation in order to reconstruct the average value of the missing block. The second follows, which will apply the AC estimation technique.

The proposed technique is tested with the I-frames of the test sequences (football, foreman, bus, mobile, enterprise and garden). The following sections show the experimental results when DC and AC estimation techniques are applied.




(a) (b)




(c) (d)

Figure 3. (a) corrupted I-frame, (b) with DC estimation, (c) DC with AC estimation and (d) error free frame

Table 1 shows the experimental results when only DC estimation is applied to the corrupted image and also the results when both DC and AC estimation are applied to the corrupted frames.

I-frame	Corrupted Image (PSNR)	DC Estimation (PSNR)	DC and AC estimation (PSNR)
Foreman	14.3774	21.8790	22.1292
Football	16.8023	24.6235	24.8120
Bus	16.1496	18.5472	18.6037
Mobile	14.1080	20.4171	20.4728
Garden	15.8346	25.0824	25.0678
Enterprise	17.8922	24.9409	25.0827

Table 1. Experimental results of proposed DC estimation and of DC with AC estimation

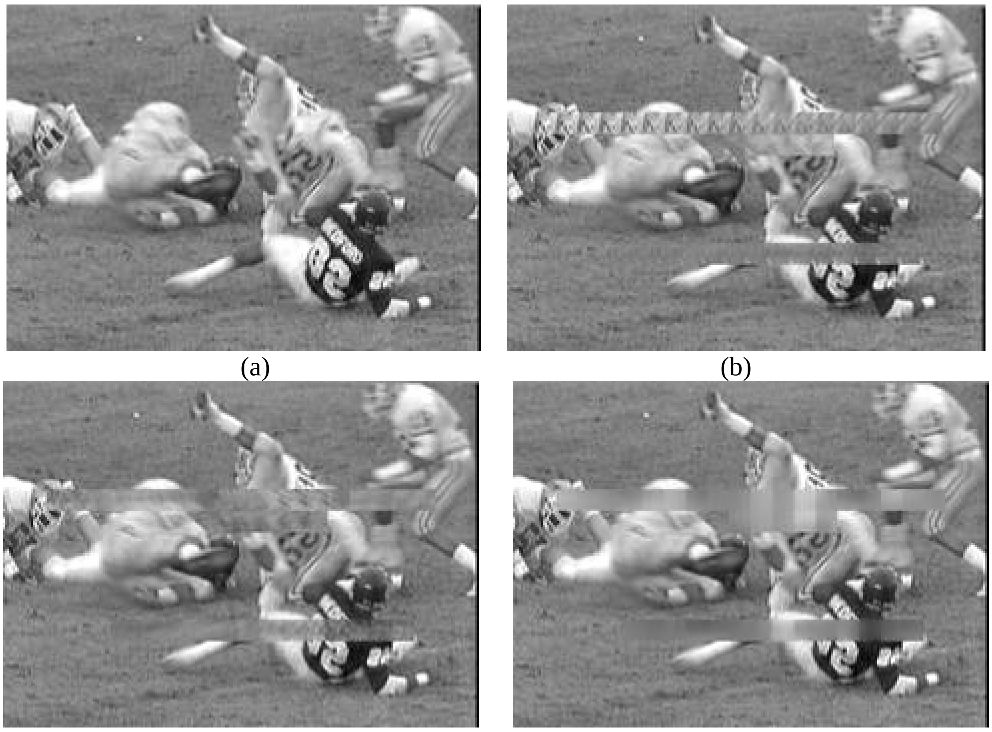
The results for DC and DC with AC estimation of the football frame are shown in Figure 3.

4. COMPARISON

The proposed method performs better than previously published techniques [1] & [8] for several sequences. The PSNR of reconstructed frames has been improved between ~0.009 – 4 dB. The comparison PSNRs are shown in Table 3 and the reconstructed frames are shown in Figure 4.

I-frame	Spatial Interpolation [8]	Quadrilinear Interpolation [1]	Proposed method
Foreman	21.9248^{+}	25.3982^{+++}	22.1292^{++}
Football	23.5001^{+}	24.1462^{++}	24.8120^{+++}
Bus	20.8801^{+++}	18.5950^{+}	18.6037^{++}
Mobile	18.7162^{+}	20.4547^{++}	20.4728^{+++}
Garden	21.0131^{+}	25.1167^{+++}	25.0678^{++}
Enterprise	25.7910^{++}	26.7730^{+++}	25.0827^{+}

Table 3. Comparison of the proposed and previously published methods



(a) (b) (c) (d)

Figure 4. (a) error free, (b) Spatial Interpolation, (c) Quadrilinear Border Interpolation and (d) DC with AC Estimation

5. CONCLUSION

In this paper, we have presented an error concealment algorithm based on frequency domain estimation. DC coefficients are estimated using linear weight coefficients calculated from LLS while AC coefficients can be calculated using a combination of AC estimation/prediction.

The implementation results show that the proposed method performed better than the previously published techniques for several sequences.

6. REFERENCES

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