Proceedings of the 6th WSEAS International Conference on Multimedia Systems & Signal Processing, Hangzhou, China, April 16-18, 2006 (pp1-6)

Performance Analysis of Error Concealment Algorithms for MPEG-2 Video

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Abstract: - In this paper, three derivations of linear frequency concealments were simulated and compared. These three **E**rror **C**oncealment (***EC***) algorithms use linear frequency re-interpolation. We have implemented and compared different numbers of neighboring blocks involved during the re-interpolation. These three error concealments are **P**revious **C**oded **B**lock Linear **E**rror **C**oncealment (***PCB-EC***), **F**our **N**eighbors Linear **E**rror **C**oncealment (***4N-EC***) and **E**ight **N**eighbors Linear **E**rror **C**oncealment (***8N-EC***). The results show that 4N-EC algorithm can achieve the best performance and have PSNR increment by 8.2dB after recovery while other algorithms can only improve 1-2dB after recovery.

Key-Words: - MPEG-2, error concealment, linear frequency concealment, video processing, error recovery.

1 Introduction

Nowadays more and more video applications [1][2] and products are produced and distributed via communication network. Transmission errors [3] are likely due to the nature of the networking system. Compressed video [1][2] is more fragile to transmission errors, due to its highly organized structured. Consequently the quality of pictures is degradated.

Error **C**oncealment (***EC***) [5] makes use of the redundancies that still remain in frequency, temporal or spatial domains with the compressed video bit stream. There are three commonly used EC algorithms:

1. Temporal Error Concealment
2. Spatial Error Concealment
3. Frequency Error Concealment

In Temporal Error concealment the damaged Macroblock in P and B frame is concealed by the temporally corresponded Macroblock (the block specified by the motion vector) in the previous I-frame. Aign and Fazel [5] simulate a transmission channel (Rayleigh fading channel for the base layer and Rice fading channel for the upper layers) with a packet error rate 10^{-1}, then combine the spatial error concealment (*for I- frame*) and temporal error concealment for (*P- B- frame*).

S. Aign et al. [5] have proposed and tested several different approaches related to Spatial Error Concealment. Spatial error concealment related to I-frame pictures. Two methods are proposed to interpolate the pixel values. (1) A pixel is interpolated from two pixels in its two nearest boundaries. (2) A pixel in the Macroblock is interpolated from the pixels in all four boundaries. These suggested methods take advantage of the spatial smoothness property of picture. They ideally work well for I-Frames, rather than P- B-Frames, since the DCT differencing-block in Inter-Coded Maroblock for the P- B-Frame does not have the spatial correlations.

Hemami and Meng [6] suggested the use of Frequency Error concealment. In linear reinterpolated algorithm the damaged coefficient from the corresponding coefficients in its four neighbor blocks with pre-set interpolation coefficients. By reconstructing each lost coefficient in a block as a linear combination of the same coefficient from neighboring blocks, the block correlation is maintained and the structure of the reconstructed block is determined by the structure of those neighboring blocks. When all coefficients of damaged block are lost, this frequency domain based error concealment is equivalent to the interpolation of each pixel in its block from the corresponding pixels in its four adjacent blocks. The quality of the reconstructed picture is determined by the accuracy of the algorithm, since the error in the DCT coefficients will be magnified into the spatial domain as they contain compressed information, especially after de-quantization process.

The experimental results from [5][6] can only have an average increment of PSNR by 1 dB after their EC recovery algorithms.

In this paper, three Error Concealment (EC) algorithms: **P**revious **C**oded **B**lock Linear **E**rror **C**oncealment (***PCB-EC***), **F**our **N**eighbors Linear **E**rror **C**oncealment (***4N-EC***) and **E**ight **N**eighbors Linear **E**rror **C**oncealment (***8N-EC***) were implemented and tested. We found that the proposed 4N-EC algorithm can have PSNR increment by 8.2dB after recovery.

Section 2 explains the details about the proposed Error Concealment algorithms. Section 3 illustrates the Linear Re-interpolation, PCB-EC, 4N-EC and 8N-EC algorithms. Section 4 shows the results of these three EC algorithms under ¼ Y component erasing noise. Section 5 is the conclusion.

2 The proposed error concealment algorithm

Figure 1 shows the block diagram of the proposed **E**rror **C**oncealment ***EC*** process. The Parity Detection provides the location of errors. The blocks with error are marked as Error Block. If a block is report as Correct Block, it is passed through the Parity Filter. The filtered Correct Block on one hand is saved into My Frame Buffer; it is also passed to the normal MPEG routines which are known as "Inverse Quantization", "Saturate", "Inverse DCT". Finally it is written into "MPEG Frame Buffer".

After Parity Detection, if a block is reported as an Error Block, it is passed through Parity Filter, but the filtered Error Block will be marked as error and save back to My Frame Buffer. The Linear Recovery routine won't be triggered until all blocks of current frame are fully loaded into "My Frame Buffer". This ensure all neighbor blocks of each block are ready. Therefore the Linear Recovery" routine scans through the buffer, and re-interpolates the blocks, which are marked as Error Block. Once the Error Blocks are concealed, the recovered blocks are written back into My Frame Buffer in case other error block might use it. It will be passed back to the normal MPEG routines and overwrite to the MPEG Frame Buffer.

In this Module, three adapted Frequency Domain Linear Recovery Algorithm are simulated, they are:

- **P**revious **C**oded **B**lock Linear **E**rror **C**oncealment (***PCB-EC***);
- **F**our **N**eighbors Linear **E**rror **C**oncealment (***4N-EC***); and
- **E**ight **N**eighbors Linear **E**rror Concealment (***8N-EC***)

These three algorithms use the same linear re-interpolations, only differing in number of neighbor blocks involved in the linear re-interpolation process.

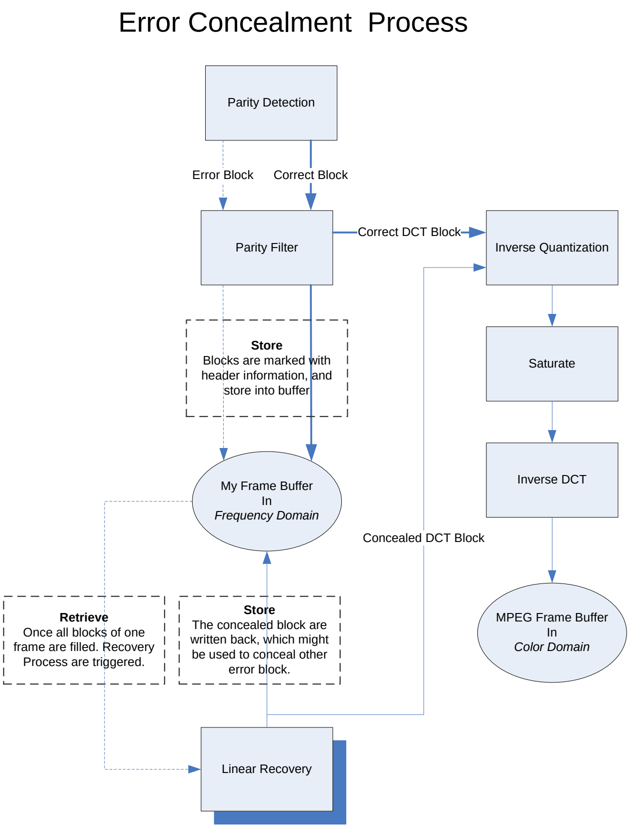

Figure 1 The block diagram of the proposed EC process

3 Linear re-interpolation

There are two key components Probability Filter and Linear Re-Interpolation involved during the re-interpolation of error block.

The example shown in Figure 2 is a re-interpolation of coefficient zero, from Neighbor Block One and Error Block. Probability Filter takes three inputs: the value of coefficient zero from both Error Block and Neighbor Block One and the zeroty value of index zero.

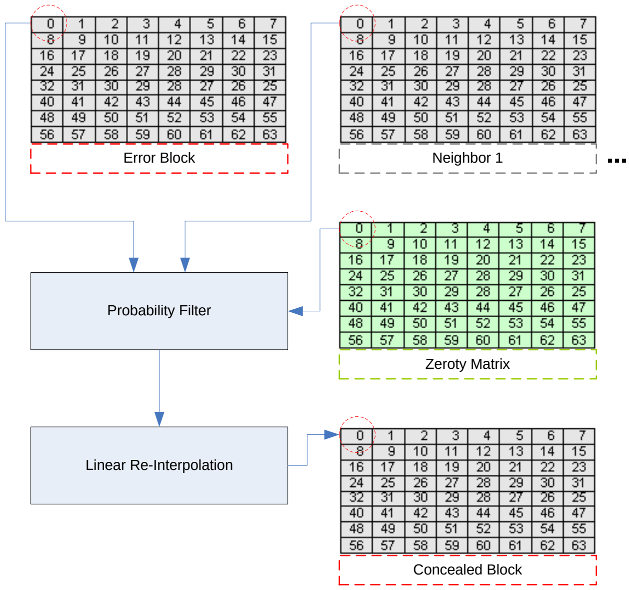

Figure 2 Re-Interpolate Coefficients Zero

3.1 Previous Coded Block Linear Error Concealment (PCB-EC)

In this algorithm the neighbor block will only be the previous coded homogenous-block (Y, Cr, Cb), under chroma-down sampling 4:2:0.

This algorithm requires limited amount of buffer and computational cost. The buffer is required to store previous coded DCT block. The computational cost merely involves linear interpolation between the error block and previous block.

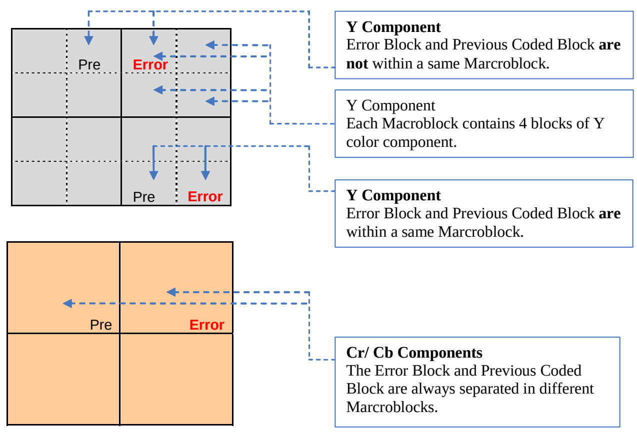

Figure 3 Previous Coded Block Linear Error Concealment Neighbor Allocation (4:2:0)

3.2 Four Neighbor Linear Error Concealment (4N-EC)

In this algorithm the error block is concealed with its four neighbor blocks, which are in four distinct directions (N, S, W and E), under chroma-down sampling 4:2:0.

This algorithm requires large amounts of buffer, and moderate amounts of computational cost. The buffer is required to store all DCT blocks of current frame. The computational cost involves allocating neighbor blocks and the linear re-interpolation between four allocated neighboring blocks.

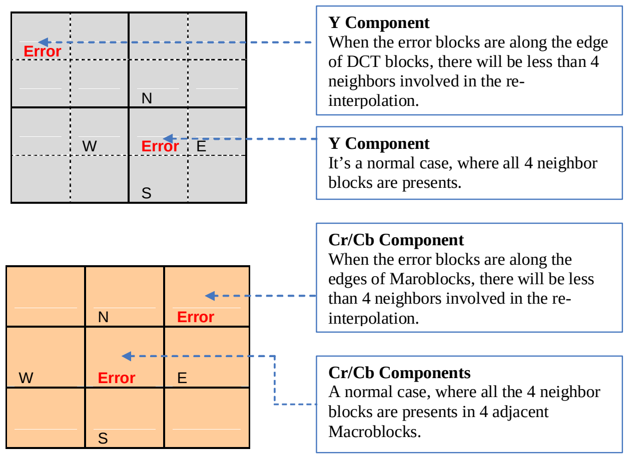

Figure 4 Four Neighbors Linear Error Concealment Neighbor Allocation (4:2:0)

3.3 Eight Neighbor Linear Error Concealment (8N-EC)

In this algorithm, the error block will be concealed with its eight neighbor blocks, which are in eight distinct directions (N, NE, E, SE, S, SW, W and NW), under chroma-down sampling 4:2:0.

This algorithm requires large amounts of buffer and computational cost. The buffer is required to store all DCT blocks of the current frame. The computational cost involves allocating eight neighbor blocks and the linear re-interpolations between eight allocated neighboring blocks.

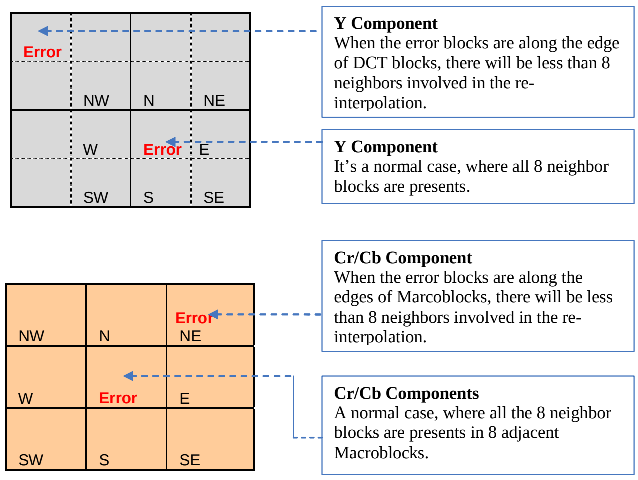

Figure 5 Eight Neighbors Linear Error Concealment Neighbor Allocation (4:2:0)

4 Testing results

In this paper, three testing results have been obtained under ¼ Y component erasing noise. Section 4.1 is the result for **P**revious **C**oded **B**lock Linear **E**rror **C**oncealment" (***PCB-EC***). Section 4.2 is the result for **F**our **N**eighbors Linear **E**rror **C**oncealment" (***4N-EC***). Section 4.3 is the result for **E**ight **N**eighbors Linear **E**rror **C**oncealment" (***8N-EC***). Table 4 shows the visual quality of video frame 0, frame 60, frame 120, frame 180 and frame 240 for these three EC algorithms under ¼ Y component erasing noise.

4.1 Test 1

Previous **C**oded **B**lock Linear **E**rror **C**oncealment (***PCB-EC***) under ¼ Y component erasing noise

This test is used to examine the performance of the concealment algorithm which simply uses previous coded homogenous-block to perform the linear re-interpolation with the error block. In this simulation the ¼ Y Component Erasing Noise is applied. Table 1 shows the PSNR results for PCB-EC under ¼ Y component erasing noise.

PSNR Results for PCB-EC			
	Before Concealment PSNR (dB)	**After Concealment PRNR (dB)**	**Increasing PSNR (dB)**
Y	18.7	23.8	**5.1**
Cr	37.6	46.8	9.2
Cb	38.2	46.9	8.7

Table 1 PSNR results for PCB-EC

According to the result in Table 1, an increment of PSNR in all three components (Y,Cr,Cb) can be identified. Particularly for Y component the PSNR is increased by 5.1 dB.

From column 3 of Table 4 it is apparent that the re-interpolated pictures are visually better. However the block effect is still quite obvious.

4.2 Test 2

Four **N**eighbors Linear **E**rror **C**oncealment (***4N-EC***) under ¼ Y component erasing noise

This test is used to examine the performance of the concealment algorithm which uses adjacent four neighbor homogenous-blocks (same type block) in N, S, E and W direction to perform the linear re-interpolation with the error block. In this simulation the ¼ Y Erasing Noise is applied. Table 2 shows the PSNR results for 4N-EC under ¼ Y component erasing noise.

PSNR Results for 4N-EC			
	Before Concealment PSNR (dB)	**After Concealment PRNR (dB)**	**Increasing PSNR**
Y	18.7	26.9	**8.2**
Cr	37.6	47	9.4
Cb	38.2	47	8.8

Table 2 PSNR results for 4N-EC

From the results in Table 2, an increment of PSNR in all three components (Y,Cr,Cb) can be identified. Particularly for Y component the PSNR is increased by 8.2 dB. From column 4 of Table 4 we find that the re-interpolated pictures are visually better when compared with PCB-EC in column 3 of Table 4. Compared with the PSNR 43.6dB without noise, the 4N-EC results show a 18.8% PSNR recovery level.

4.3 Test 3

Eight **N**eighbors Linear **E**rror **C**oncealment" (***8N-EC***) under ¼ Y component erasing noise

This test is used to examine the performance of the concealment algorithm which uses adjacent eight neighbor homogenous-blocks (same type block) in direction of N, NE, E, SE, S, SW, W and NW to perform the linear re-interpolation with the error block. In this simulation the ¼ Y Component Erasing

Noise is applied. Table 3 shows the PSNR results for 8N-EC under ¼ Y component erasing noise.

PSNR Results for 8N-EC			
	Before Concealment PSNR (dB)	**After Concealment PRNR (dB)**	**Increasing PSNR (dB)**
Y	18.7	26.6	**7.9**
Cr	37.6	47	9.4
Cb	38.2	47	8.8

Table 3 PSNR results for 8N-EC

From the results in Table 3 an increment of PSNR in all three components (Y,Cr,Cb) can be identified. Particularly for Y component the PSNR is increased by 7.9 dB. However in comparison with the PSNR 8.2 dB result in Section 4.2 (Table 2), the gain of PSNR has been dropped by 0.3 dB. From column 5 of table 4, we find that the re-interpolated pictures are visually improved. But the resulting pictures in this simulation are brighter than the results of column 4 (4N-EC).

5 Conclusion

In this paper three Error Concealment (EC) algorithms: **P**revious **C**oded **B**lock Linear **E**rror **C**oncealment (***PCB-EC***), **F**our **N**eighbors Linear **E**rror **C**oncealment (***4N-EC***) and **E**ight **N**eighbors Linear **E**rror **C**oncealment (***8N-EC***) were implemented and tested. The results in Section 4 show that 4N-EC can have the best result in EC for MPEG-2 video. Under ¼ Y component erasing noise test, Y-component achieves PSNR increment of 8.2 dB after recovery while the other algorithms in [4,5,7] can only produce a PSNR increment of 1-2 dB after recovery.

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	Before Recovery	After recovery using PCB-EC	After recovery using 4N-EC	After recovery using 8N-EC
Frame 0				
Frame 60				
Frame 120				
Frame 180				
Frame 240				

Table 4 The results from 3 different error concealment algorithms under ¼ Y erasing noise