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Analysis and application of error concealment tools in AVS-M decoder*

YANG Cheng[1], SHI Lei[†2], WU Xiao-yang[2], ZHANG Ci-xun[2]

([1]*School of Computer Science, Zhejiang University, Hangzhou 310027, China*)

([2]*Institute of Information and Communication Engineering, Zhejiang University, Hangzhou 310027, China*)

[†]E-mail: horatio_222@126.com

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Abstract: Audio Video coding Standard (AVS) is the latest audio and video coding standard of China. AVS Part 7 (also known as AVS-M) targets mobility applications where error concealment is of great importance. This paper first briefly introduces the general concept of error concealment. Then two error concealment schemes are proposed and implemented on AVS-M decoder under different test conditions. Simulation results of the schemes and suggestions on how to use these tools are also provided.

Key words: Audio Video coding Standard (AVS), Error concealment, Video communication

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INTRODUCTION

Audio Video coding Standard (AVS) is developed by AVS Working Group of China, which was authorized and established by the Science and Technology Department of the Ministry of Information Industry of China in June, 2002.

AVS video is an application driven coding standard with two separate parts for different applications: AVS Part 2 and AVS Part 7. AVS Part 2 targets high definition digital video broadcasting and AVS Part 7 (also known as AVS-M) targets low picture resolution mobility applications.

Similar to H.264/AVC, AVS video coding tools include the following major parts: integer transform, intra and inter-picture prediction, in-loop de-blocking filter and context-based 2D variable length coding. However, AVS is much simpler than H.264/AVC while similar compression performance is achieved. The compression ratio of H.264/AVC and AVS is about twice that of MPEG-2, while MPEG-4 is about 1.4 times that of MPEG-2.

For more information about AVS video coding, the readers are referred to (Yu *et al*., 2005).

CONCEPT OF ERROR CONCEALMENT

Error concealment in video communication is a very challenging topic. Many techniques have been proposed to deal with the transmission error problem. Generally, all these techniques can be categorized into three kinds: forward error concealment, backward error concealment and interactive error concealment.

Forward error concealment refers to techniques in which the encoder plays the primary role. Until now, the most popular and effective scheme of forward error concealment is layered coding combined with transport prioritization by Ghanbari (1989) and Zhang *et al*.(1994), which partitions video data into more than one layer with different priority. The layer with higher priority is delivered with a higher degree of error protection. Better quality can be achieved when more layers are received at decoder side. Besides this, multiple-description coding by Wolf *et*

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al.(1980) sends video information in several different parallel channels in order to reduce the risk of channel error; robust waveform coding by Hemami and Gray (1994) adds some extra redundancy to bit stream for error concealment; etc.

Backward error concealment refers to the concealment or estimation of lost information due to transmission errors in which the decoder fulfills the error concealment task. Motion-Compensated Temporal Prediction by Kieu and Ngan (1994) uses previous decoded frame data to recover the lost blocks in the current frame; Maximally Smooth Recovery by Wang *et al*.(1993) weights the spatial, temporal and frequency domain prediction of the lost macroblock, to find the smoothest recovered blocks; Projection onto Convex Sets by Sun and Kwok (1995) utilizes the direction of macroblock to make the concealment data have the same direction as the neighboring macroblocks through iterative process; etc.

The decoder and encoder interactive techniques achieve the best reconstruction quality, but are more difficult to implement. Generally speaking, a feedback channel is needed from decoder to encoder and low time delay should be guaranteed. Selective Encoding for Error Concealment by Wada (1989) judges the information from feedback channel, and then selects the best reference frame; Re-transmission for Error Concealment by Marasli *et al*.(1996) retransmits the picture data containing error to improve decoded quality; etc.

ALGORITHM AND ANALYSIS

In this paper, only backward error concealment at decoder side is discussed. Two error concealment schemes with different complexity and performance trade-offs are proposed, implemented and analyzed.

Error concealment scheme 1

The error concealment scheme 1 is to replace the lost macroblocks, including intra and inter macroblocks, with data in order to make a picture look smoother, without obvious influence on decoding speed.

For lost macroblock in I frame, the most probable intra prediction mode defined by AVS-M intra prediction algorithm is used as the intra prediction mode. And then the lost macroblock is reconstructed using this intra prediction mode and available data on neighboring macroblocks.

The result of this error concealment scheme depends on the actual picture data. Because the intra prediction cannot reconstruct the details of the picture, this scheme works well at smooth region, such as water, sky and wall; but at regions with complex texture, such as face and boundary, the concealment result of this method is not satisfactory enough.

For lost macroblocks in P frame (B frame is not supported in AVS-M), temporal prediction is used for the concealment. In this scheme, all lost P macroblocks are assumed to be 16×16 type macroblock, and the motion vectors of neighboring macroblocks are used to predict the current macroblock motion vector using the algorithms defined in AVS-M standard. With the predicted motion vector, the lost macroblock is recovered by the macroblock in decoded reference frames through motion compensation algorithm in AVS-M standard.

The result of this error concealment scheme mainly depends on the accuracy of the predicted motion vector. If the predicted motion vector deviates from the true motion vector too much, there may be erroneous regions which are obviously un-continuous in the reconstructed picture. It is found that AVS-M motion prediction algorithm has good performance here. Subjective experiments show that if I frame does not contain error, and the picture does not contain large motion, then the error distortion caused by 3% error channel using bit streams with intra period set to 60 is almost unnoticeable.

Error concealment scheme 2

In error concealment scheme 1, when the reference frame contains error, then the current decoded frame will also contain error even though all the data are correctly received. This phenomenon is known as error propagation. The quality will be badly degraded if there is error propagation. In error concealment scheme 2, other decoded frame can also be used to provide better performance. In the following, we first discuss the methods for P frame, and then the methods for I frame.

For lost macroblock in P frames, the technique of reference frame selection is used. In AVS-M standard, one P frame could have two reference frames at most.

To conceal one lost macroblock in P frames, if its reference macroblock is a concealed macroblock, then the decoder will check whether the other reference frame is available and is similar enough to the original reference frame. If so, the other reference frame is used instead of the original reference frame which contains error. To reduce implementation complexity, the predicted motion vector is not changed. The difference of the reference frames is determined by calculating the SAD of pixels in two reference frames, given by the following formula:

$$D=\frac{1}{N}\sum_{P=1}^{N}\left|P_{\mathrm{ref1}}(x,y)-P_{\mathrm{ref2}}(x,y)\right|. \tag{1}$$

In Eq.(1), $P(x,y)$ is the pixel located in (x,y) of the reference frame. N is the number of pixels chosen. If the difference D is less than a pre-defined threshold Δ, then the reference frames are considered similar. For low complexity applications, smaller value of N can be chosen, for example, only the first line, the middle line and the last line of pixels are used.

For lost macroblock in I frames, the neighbouring pixels of the current macroblock and the co-located pixels in the nearest reference frame are checked to see whether they are similar enough according to Eq.(1). If so, then the co-located macroblock in that reference frame is copied directly as the reconstructed macroblock. Otherwise, intra prediction using most probable mode in scheme 1 is used.

This error concealment method is very useful when there is no scene change between current I frame and the previous P frame, which may be common in many video applications since there will be one I frame inserted every 0.5 or 1 second for the purpose of random access.

This error concealment method is more efficient than the method used in scheme 1 because intra prediction cannot predict the details of the picture but the directly copy may retain the detail if the frames are similar. Moreover, improved quality of I frame will be of great importance for improving the quality of successive P frames.

EXPERIMENT AND ANALYSIS

Experimental results are given in this section. The bit stream is generated by AVS-M encoder version 2.5a with about 120 bytes per slice. QP is set to 32 and intra period is set to 30. The coded bit stream is then passed through the simulated channel with 3%, 5%, 10% error ratio respectively. The error pattern files accompanied with JVT Q15I16r1.doc are used in the experiments. In the simulation, the sequence parameters, picture parameters, picture headers and slice headers are protected and will not be lost. Only slice data may be dropped. The output bit stream is decoded by AVS-M Golden C decoder 1.60, which is realized and transplanted to Omap1510 system to meet the requirements of DSP.

In the first experiment, we use the test sequence Foreman (CIF). The coded bit stream is passed through 3% and 10% simulated error channel. Four tests are carried out. In test 1, no error concealment is used. In test 2, scheme 1 is employed. In test 3, besides scheme 1, scheme 2 for P frame is also used. In test 4, scheme 1 and scheme 2 for both P and I frame are used.

The results are given in Fig.1. Test 1 with no error concealment has the worst picture quality, as

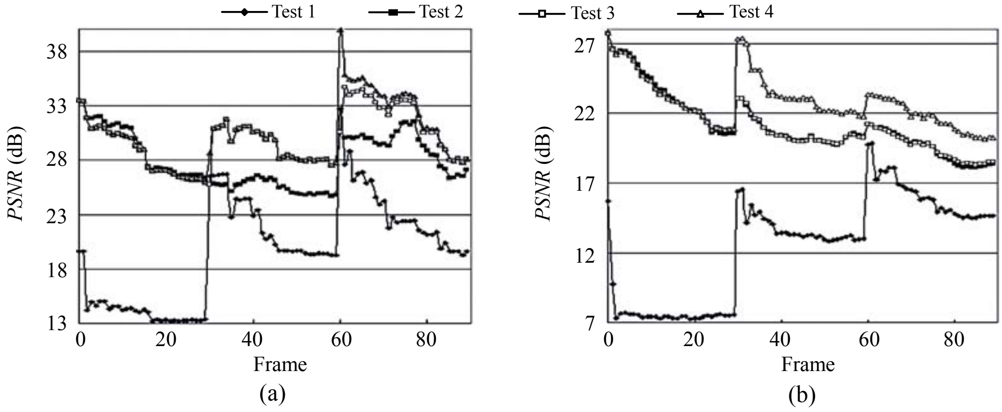

Fig.1 Decoded *PSNR* comparison. (a) 3% simulated error channel; (b) 10% simulated channel

expected. Test 2 with scheme 1 has significant improvement in *PSNR* over test 1. Test 3 with scheme 1 and scheme 2 for P frame has gain over test 2 in *PSNR* when error ratio is low (3%). But when error ratio is high (10%), the gain tends to be little, which is mainly because when error ratio is high, the chance is higher that both reference frames are reconstructed with error concealment algorithm. Besides this, the reference frame selection process in scheme 2 also brings error. However, scheme 2 for P frame employed in test 3 does improve subjective quality. Test 4 with scheme 1 and scheme 2 for both P and I frames has obvious *PSNR* gain over others, especially when error ratio is high. Moreover, since the quality of I frame is improved, the quality of the following P frames is also improved. When the error ratio is low and as a result there are few errors in I frame, not much gain is obtained.

In the second experiment, we use the test sequence Mobile (CIF). The coded bit stream is passed through a 5% simulated error channel.

Figs.2a~2c are decoder outputs without error concealment. There is no obvious distortion in Fig.2a. In Fig.2b it can be seen that on the calendar the data 29, 30, 31, 1, 2 are not in the right position. This is because the predicted motion vectors of the corresponding lost macroblocks were not accurate enough. Moreover, the error is propagated since these macroblocks are used for reference of Fig.2c.

Figs.2d~2f are corresponding decoder outputs with scheme 2. Similarly, there is no obvious distortion in Fig.2d. In Fig.2e, the error appears at the same position. In Fig.2f, the decoder detects that the predicted motion vectors of the lost macroblocks currently being decoded points to concealed macroblocks in Fig.2e. It then finds that the other reference frame is

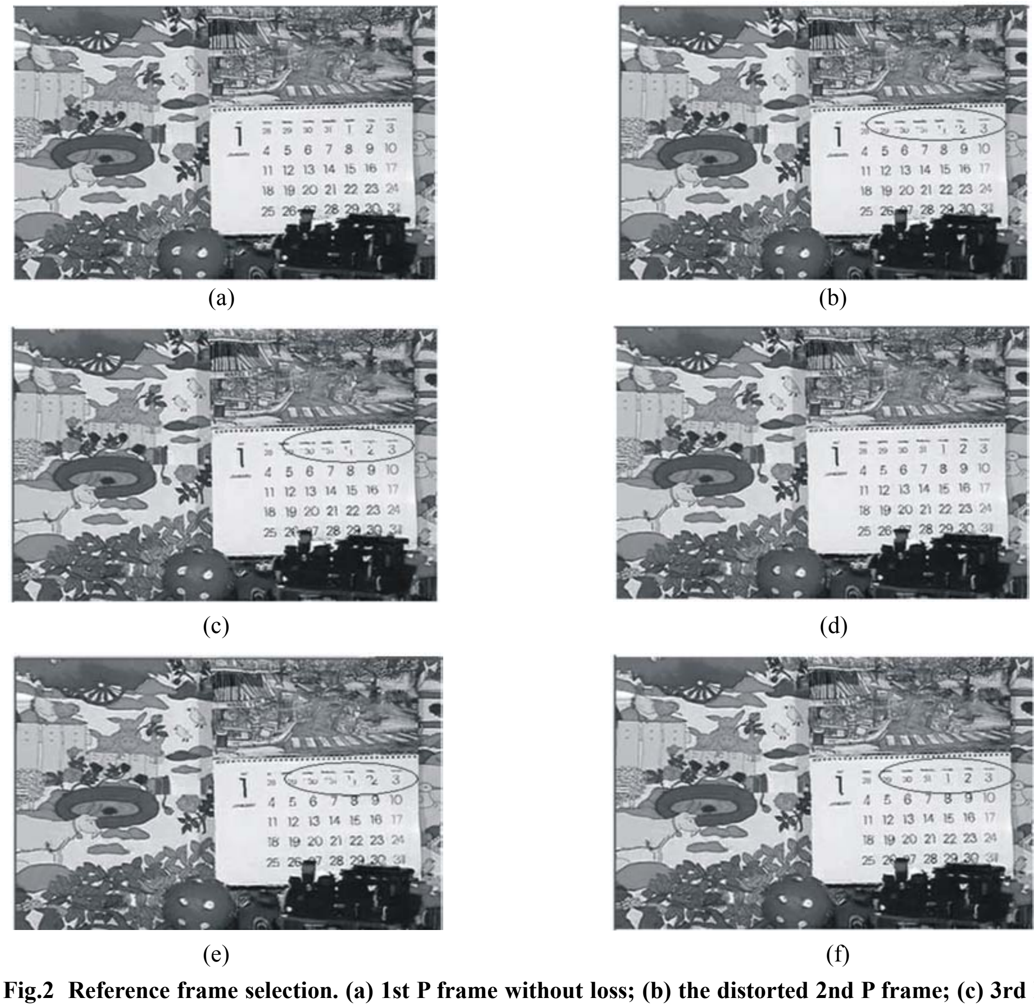

Fig.2 Reference frame selection. (a) 1st P frame without loss; (b) the distorted 2nd P frame; (c) 3rd P frame with error propagation; (d) 1st P frame without loss in scheme 2; (e) the distorted 2nd P frame in scheme 2; (f) 3rd P frame in scheme 2

correctly decoded and the two reference frames are similar enough to replace each other. So the other reference frame is used instead of the original reference frame. From the results in Fig.2, we can see that the reconstructed picture quality with scheme 2 is generally better.

CONCLUSION

In this paper, two error concealment schemes are proposed and implemented on AVS-M. Extensive experiments show that scheme 1 has significant improvements in both objective and subjective quality when transmission error occurs. Scheme 2 for P frame performs well especially when error ratio is low while scheme 2 for I frame performs well especially when error ratio is high and also has great impact on the following P frames. Combination of these two schemes yields the best quality.

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