REDUCING DRIFT FOR FGS CODING BASED ON MULTIFRAME MOTION COMPENSATION

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ABSTRACT

Fine Granularity Scalability (FGS) in MPEG-4 and some enhanced FGS coding techniques have been studied recently for video streaming. However, a problem of drifting may emerge due to the difference of reference frames used in the encoder and decoder for those enhanced FGS coding schemes. In this paper, we propose incorporating multiframe-based motion compensation into an FGS coding scheme to further improve the coding efficiency and error robustness. It has been shown that multiple frames based FGS coding scheme has better coding efficiency than the conventional one-frame based FGS video coding, and more importantly, the new one can alleviate the drifting problem significantly. The proposed approach is implemented within a one-loop FGS coding scheme based on H.26L framework.

1. INTRODUCTION

With the rapid development of multimedia and network technologies, video streaming or multimedia applications over the Internet or wireless networks have become more and more popular. The most challenging problem of these applications is that the network bandwidth is not always constant due to the heterogeneous nature of networks, and we need to adapt the bit-rate of coded video stream to the available bandwidth. Recently, Fine Granularity Scalability (FGS) has been developed for video streaming applications [1], which has been accepted by MPEG standard as one of the video streaming tools [2].

The FGS coding is also a layered coding technique. Bit-plane coding method [3] is employed for the enhancement layer coding and enhancement layer bit-stream can be truncated at any position within a particular frame, such that at the decoder side, the video quality can be improved in fine granularity by decoding more enhancement bit-steam data. The original FGS coding scheme uses open-loop coding structure, where temporal prediction is only based on the low quality base layer reference. This assures drift-free coding and provides FGS good error recovery capability from the enhancement layers errors. However, comparing with the single layer non-scalable video coding scheme, the coding efficiency of FGS is also decreased as the prediction is always based on the reconstructed low quality image.

The FGS open loop coding structure is the main reason for the dropping of coding efficiency. Recently, several methods have been successfully proposed to improve the original FGS coding scheme. Most of the methods improve the predictive coding and reduce the temporal redundancy by exploiting the enhancement layer information. Those methods can be classified into two groups: one-loop FGS, and two-loop FGS. The one-loop FGS improves the prediction by introducing several enhancement bit-planes directly to the motion compensation loop of the base layer, thus constructing a high quality base layer reference. Motion-Compensation FGS (MC-FGS) [4] is one of the one-loop coding schemes. The coding efficiency is improved by one-loop FGS scheme with only limited cost and complexities. However, if the enhancement bit-planes used for prediction cannot be received by the decoder, severe drifting problems would occur. Two-loop FGS coding scheme uses one more motion compensation loop in the enhancement layer to improve the coding efficiency, and the base layer remains the same as the original FGS. Several improved FGS coding techniques have been proposed based on the two-loop structure. Progressive FGS (PFGS) [5] and Robust FGS (RFGS) [6] use different mechanisms to construct the enhancement layer reference, and at the same time, to keep the drifting effect low.

Both one-loop FGS and two-loop FGS can improve the coding efficiency of the original FGS when the enhancement layer bit-planes used for the high quality reference prediction can be successively received and decoded. However, packet loss in those enhancement layer data will inevitable cause drifting problems. PFGS and RFGS apply some mechanisms to reduce the drifting effects, which is at the expense of loss in coding efficiency and increasing in the cost and complexity. There are many methods proposed for drifting reduction [7], and some have been successively applied for FGS.

Recently, a new part of MPEG-4 standard: H.26L has been developed jointly by MPEG and ITU-T. H.26L adopts some new techniques and has been proved to be an attractive choice for video streaming over the Internet. In this paper, we employ the multiple references motion compensation in FGS coding to develop a more robust FGS coding scheme based on the H.26L framework. The proposed FGS coding framework is discussed in the next section. In Section Three, we briefly analysis error propagation for single-frame based FGS and the proposed multiple-reference based FGS coding method. The performance is demonstrated by experimental results in Section Four. The paper concludes in Section Five.

2. MULTIFRAME BASED FGS

Single-reference based block motion compensation has been widely adopted by video coding schemes, where only the immediately previous reconstructed frame is used as reference for motion compensation. To achieve better coding efficiency, multiframe based motion compensation scheme such as long-term memory motion-compensation prediction (MCP) was proposed in [8]. A larger memory buffer is used in the long-term memory based MCP scheme, which stores several previous reference frames, and the motion-compensation is executed based on multiple references in the memory buffer, instead of just one previous frame. Long-term memory MCP was proposed to use up to 50 previous references, and was reported to achieve significant coding gain. In addition, multiple references motion compensation scheme has an inherent ability of alleviating the effects of transmission errors [9], thus it is more robust and efficient for video coding and transmission over error-prone channels, such as wireless network. Various video coding standards, like H.263+ and H.26L also support multiple references as one of the tools to improve coding efficiency and resilience towards channel errors. In H.26L standards [10], motion search can be conducted based on multiple references stored in the memory buffer.

The proposed FGS coding scheme in this paper applies multiple references for motion compensation to further improve coding efficiency and more importantly to alleviate drifting effect in the one-loop or two-loop FGS. Considering a limited size of memory buffer, the number of reference frames has to be reasonably chosen, which is suitable for practical applications. For instance, in H.26L TML 9.0 source code, the number of reference frames can be set from 1 to 5. The two-loop improved FGS coding schemes use additional high quality references in the enhancement layer for better motion compensation. Applying the multiple references in the two-loop FGS coding scheme will again double the size of memory buffer, which may not be desirable for some applications. The one-loop FGS coding structure has been reported as a simple and efficient approach, which requires little complexity and cost. However it will cause severe drifting problem in the case that errors occur in the enhancement bit-planes used for the high quality reference reconstruction. Therefore we consider integrating the multiframe motion compensation approach with the one-loop FGS coding structure to reduce the drifting effect. The proposed encoder is shown in Figure 1, where multiframe-based motion estimation and compensation is employed.

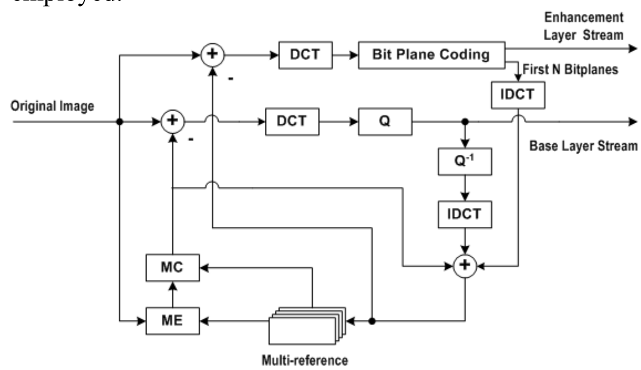
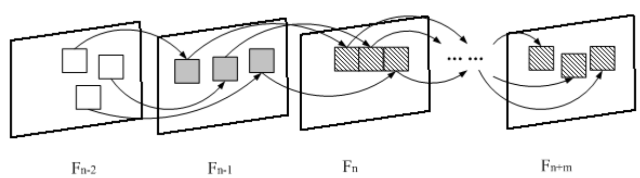


Figure 1 Multiframe motion compensation for one-loop FGS

3. ANALYSIS OF ERROR PROPAGATION

The one-loop or two-loop FGS coding schemes improve the coding efficiency by introducing some enhancement layer data to the reference. As those enhancement layer data used for temporal prediction may be lost due to the network congestion or transmission error, drift occurs when the decoder cannot construct the same reference as that for encoder. It is worthwhile to mention here that since the bit-plane coding method is used in the enhancement layer, the loss of one bit-plane in the feedback data would affect all the MBs in the reference. For single-frame based FGS coding scheme that employs higher quality references, the MBs in the current frame are predicted from the best-matched MBs in the constructed reference. As shown in Figure 2, the current frame F_n is predicted from the immediately previous reconstructed frame F_{n-1}, and the prediction of F_{n-1} refers to F_{n-2}. Without loss of generality, assume that no errors occur before frame F_{n-1}, while the enhancement layer part used for high-quality reference reconstruction in frame F_{n-1} is lost, thus drifting will occur in the following frame F_n. Fig. 2 illustrates the drifting in frame F_n and its propagation to the following frames, where all the inter-coded MBs in and after Frame F_{n-1} will be affected until an intra-coded frame comes.

In contrast, multiple-frame references would alleviate the drifting problem. The MBs in the current frame F_n will select the appropriate matching blocks from multiple references in the memory buffer based on some selection criteria. This provides a path for some MBs to skip the errors contained in some previous frames. As shown in Figure 3, the enhancement layer used for high-quality reference construction in the previous frame F_{n-1} is lost. The data loss would not only decrease the quality of the reconstructed frame F_{n-1}, but also affect the MBs in the following frames that predict from them. However, for those MBs that reference other error-free frames, there would be no error-drifting problem. For example, the MB with slashed pattern in frame F_n is affected due to drifting; while the MBs represented using white rectangular boxes in Frame F_n are not affected since they are predicted from the error-free frame F_{n-2}. It can be easily seen that similar cases will repeat for the following frames, thus improving the error robustness. There are two extremes existing, i.e., the worst case and the ideal case. The worst case occurs when all the MBs in F_n are predicted from those in F_{n-1}, and the ideal case appears when no MBs in F_n are predicted from those in F_{n-1}, thus no drifting in the frame F_n.



: MBs without errors. drifted MBs.

: MBs with their corresponding enhancement layer part lost.

Figure 2 Drifting and error propagation for single-frame based one-loop or two-loop FGS

A detailed mathematical analysis of error propagation has been made, which shows that the probability of error propagation using multiple references is lower than that using single reference. However, due to page limit, the derivation is not given here.

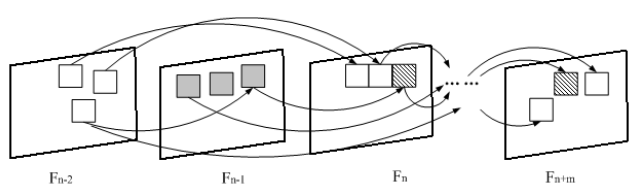


Figure 3 Drifting and error propagation for multi-frame based one-loop or two-loop FGS

4. SIMULATION RESULTS

In this section, we present the simulation results for the multiframe based one-loop FGS coding compared with its single-frame based counterpart. The multiframe FGS coding scheme was implemented by integrating with H.26L source code, where the H.26L coding scheme (TML 9.0) using five reference frames was employed. Only little modification is required for the integration without additional buffer space. Two bit-streams were generated for the base layer and enhancement layer, respectively. Without loss of generality, we only consider the first three bit-planes in the enhancement layer and, for simplicity, assume that the first three bit-planes are packetized into one packet.

Table 1 Coding parameters for the simulations

Coding Parameters		Multiframe	Single
No. of references		5	1
No. of frames coded		100	
Coding pattern		IPPP…	
Frame rate		10 frames/s	
Quantization		I (24), P (24)	
Base layer bit-rate (kbps)	Carphone	20.83	20.92
	Foreman	23.57	23.86

The simulations were performed with different packet loss ratios of 5%, 10%, 15%, 20%, 25%, and 30%, respectively. All the following results are averaged over 50 random packet loss patterns for each packet loss ratio. The peak signal-to-noise ratio (PSNR) results for sequences "Carphone" and "Foreman" are illustrated in Figure 4, where the PSNR results for both the base layer and enhancement layer are measured. With no packet loss, the PSNR results for the multiframe FGS are similar to or slightly better than those for one-frame FGS. As the packet loss rate increases, it is clear that the PSNR results for the multiframe FGS are becoming better than those for the one-frame FGS. For example, for the sequence "Carphone" with packet loss rates of 5%, 10%, 15%, 20%, 25% and 30%, the base layer PSNR results for multiframe FGS are 0.40dB, 0.49dB, 0.51dB, 0.52dB, 0.58dB, and 0.54dB higher than those for single-frame FGS, respectively, comparing with that there is only 0.22dB improvement at zero packet loss rate. The similar trend can be observed for the enhancement layer PSNR results by comparing the multiframe and one-frame FGS.

Figure 5 illustrates the frame-by-frame PSNR result for the coded sequence "Foreman", which is obtained at loss ratio of 15%. We can see that the PSNR differences for some frames can be up to 4-5 dB, either in the base layer or enhancement layer. It should be highlighted that the difference between single-frame and multiframe FGS becomes larger and larger with the frame number, which experimentally validates the statement that drifting effect can be reduced significantly using the multiframe based FGS. It can be expected that the performance will be further improved by using a larger memory buffer.

5. CONCLUSIONS

How to improve coding efficiency for FGS video coding is a research challenge, which attracts a great deal of interests and efforts from researchers. A few algorithms have been developed which, to different degrees, incorporate enhancement layer for better motion compensation. However, the problem of drifting effect emerges when the enhancement layer is lost in the decoder side. In this paper, we have developed multiple-reference based FGS video coding scheme for drift reduction, thus improving reconstructed video quality significantly. The proposed scheme has been implemented based on the one-loop FGS coding structure, where high quality references are reconstructed by introducing several enhancement bit-planes. Experimental results have substantially demonstrated that multiple-reference based FGS had significant improvement over single-reference based FGS.

REFERENCES

[1]. W. Li, "Overview of Fine Granularity Scalability in MPEG-4 Video Standard," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 11, no. 3, pp.301-317, Mar. 2001.

[2]. Video Group, "Text of ISO/IEC 14496-2/FDAM4", ISO/IEC JTC1/SC29/WG11, N3904, Pisa, Italy, Jan 2001.

[3]. F. Ling, W. Li, and H. Sun, "Bit-plane coding of DCT coefficients for image and video compression," *in Proc. SPIE Visual Communications and Image Processing (VCIP),* San Jose, CA, pp.500-508, Jan. 25-27, 1999.

[4]. M. van der Schaar and H. Radha, "Adaptive motion-compensation fine-granular-scalability (AMC-FGS) for wireless video," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 12, no. 6, pp. 360-371, Jun. 2002.

[5]. F. Wu, S. Li and Y.-Q. Zhang, "A framework for efficient progressive fine granularity scalable video coding", *IEEE Trans. Circuit Syst. Video Technol.*, vol. 11, no.3, pp.332-344, Mar. 2001.

[6]. H. Huang, C. Wang and T. Chiang, "A robust fine granularity scalability using trellis-based predictive leak", *IEEE Trans. Circuits Syst. Video Technol.*, vol. 12, no. 6, pp.372 –385, Jun. 2002.

[7]. F. Wu, S. Li, B. Zeng, and Y.-Q. Zhang, "Drifting reduction in progressive fine granularity scalable video coding", *Picture Coding Symposium (PCS),* Seoul, Apr. 2001.

[8]. T. Wiegand, X, Zhang, and G. Girod, "Long-term memory motion-compensation prediction", *IEEE Trans. Circuit Syst. Video Technol.*, vol. 11, no. 9, pp. 1011-1021, Sept. 2001.

[9]. M. Budagavi and J. D. Gibson, "Multiframe video coding for improved performance over wireless channels", *IEEE Trans. Image Processing*, vol. 10, pp. 252-265, Feb. 2001.

[10]. "H.26L Test Model Long-Term Number 9 (TML-9) draft0", ITU-U, Q.6/SG16, Document VCEG-N83 d1, Sept. 2001.

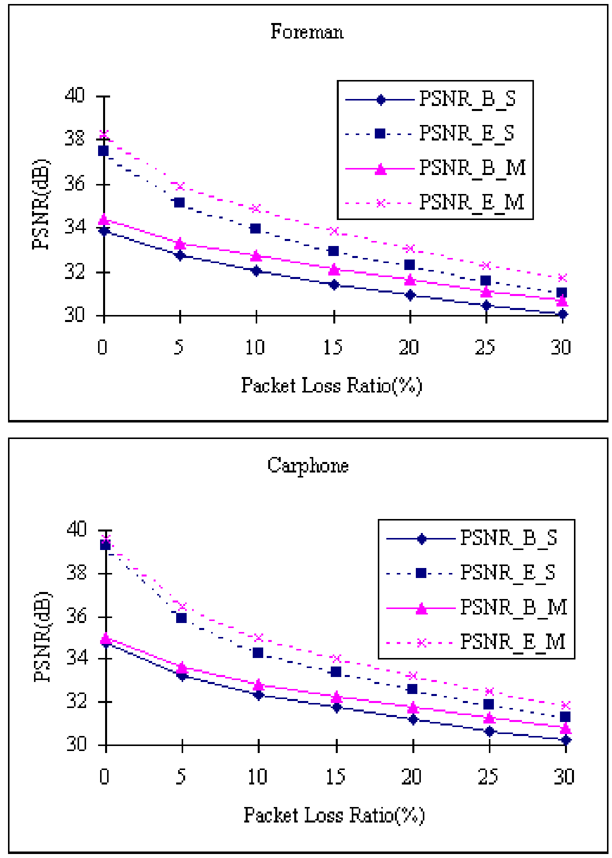


Figure 4 Average PSNR vs. Packet Loss Ratio by comparing multiframe and single-frame FGS

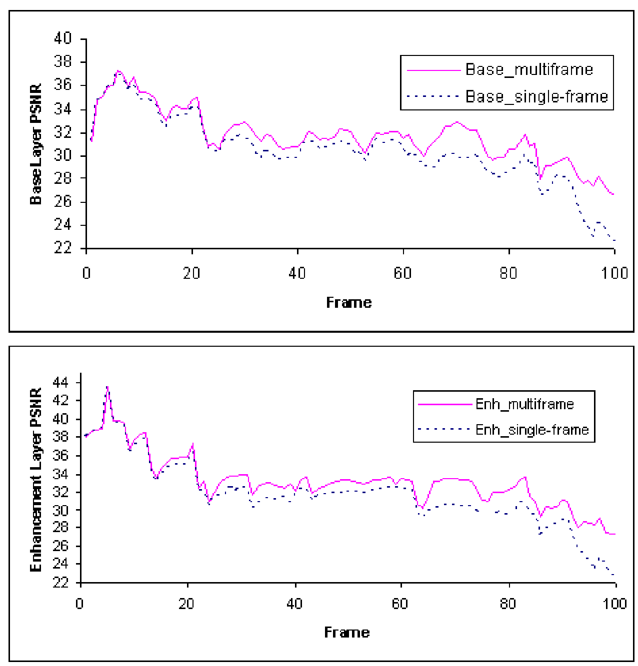


Figure 5 Frame-by-frame PSNR comparison of "Foreman" for both the base and enhancement layer