CONTENT-BASED PERIODIC MACROBLOCK FOR ERROR-RESILIENT TRANSMISSION OF H.264 VIDEO

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ABSTRACT

For the compressed video, the transmission error in one frame will propagate to the following frames, and the qualities of successive frames will drop seriously. In this paper, we present a new error-resilience scheme to alleviate the effect of error propagation in video transmission for the new coding standard H.264. In this new coding standard, multiple reference frame is adopted to achieve better coding efficiency than previous coding standard. By making use of the reference frame buffer in encoder, we can make some macroblocks in every *p* inter frame to reference the frame that is *p* frames interval away, and these macroblocks are named as periodic macroblocks. The periodic macroblock can efficiently alleviate the error propagation between the frames that contain periodic macroblocks. The selection of periodic macroblock is based on the distortion expectation of each macroblock in every *p* frame. The number of periodic macroblock in every *p* frame can be determined by the transmission bandwidth, as the periodic macroblock will consume a little more bits. The simulation results prove that the periodic macroblocks can obviously improve the quality of video with different macroblock loss rate.

1. INTRODUCTION

In most video compression coding standards, motion compensation is used to eliminate the temporal redundancy. Although this technique can significantly improve the coding efficiency, it makes bit error in video transmission become a serious problem. When one macroblock is corrupted, many macroblocks in the successive frames will be affected. Then a single bit error may become a disaster for compressed video.

To alleviate the effect of bit error, many error resilience approaches have been presented. Multiple descriptions is a widely used error-resilience concept. Wang *et al* present a multiple description motion compensation method, which employs a second-order predictor for motion-compensation [1]. The coder generates two descriptions, containing the coded even and odd frames respectively. Kim and Cho propose a multiple description of DCT coefficients [2]. They use the redundancy rate-distortion criteria to split a one-layer compressed video stream into two correlated streams or descriptions. Inserting more resynchronization signal can efficiently stop the error propagation. Hemami introduce variable-length resynchronizing codes [3]. Mohr *et al* present unequal loss protection framework, in which unequal amounts of forward error correction are applied to progressive data to provide graceful degradation of image quality as packet losses increase [4]. Forssard *et al* address a new scene-complexity adaptive mechanism to determines the best compromise between the rate allocated to encode pure video information and the rate aiming at reducing the sensitivity to packet loss [5]. Wiegand *et al* present a framework that incorporates an estimated error into rate-constrained motion estimation and mode decision [6]. Chang and Lee propose a precise error-tracking scheme [7]. By utilizing a feedback channel, the decoder reports the addresses of corrupted blocks to the encoder. Then the encoder can precisely calculate and track the propagated error by examining the backward motion dependency. The error-propagation effects can be terminated completely by INTRA refreshing. Lee *et al* propose an error-resilience image coding for DCT-based image compression [8]. Their method can successfully prevent errors from propagating across image block boundaries with little overhead. Rhee and Joshi present a new error recovery scheme, called RESCU [9]. The main benefit of the RESCU scheme is that it allows more time for transport-level recovery such as retransmission and forward error correction.

In this paper, we present a new error-resilience scheme for the new coding standard H.264. To achieve better coding efficiency, this new coding standard supports multiple reference frame during the search process of motion vector. A 16x16 macroblock in H.264 can be divided into different block shape for motion compensation, and the blocks in the same macroblock can

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select different encoded frame as reference frame to obtain minimum bit cost, as shown in figure 1.

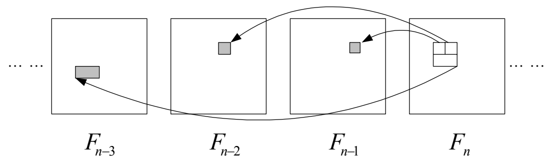


Figure 1. Multiple Reference Frame Used in H.264

When bit error occurs in one frame, some macroblocks in the successive frames may be corrupted. To alleviate the effect of error propagation, we encode some macroblocks as periodic macroblocks. The blocks in these periodic macroblocks only use the previous *p*th frame as the reference frame. And some macroblocks in this reference frame are periodic macroblocks. Then the error propagation between two frames that contain periodic macroblocks can be partially terminated. The selection of periodic macroblock is based on the distortion expectation that incorporates the transmission distortion and quantization distortion. The simulation results prove that the video quality can be significantly improved by proposed scheme.

2. CONTENT-BASED PERIODIC MACROBLOCK

To make the concept of periodic macroblock easy to understand, we introduce the concept of periodic frame first. Periodic frame refers to make every *p* frame reference previous periodic frame, which is *p* frames interval away, as shown in figure 2. *p* indicates the frame interval between two periodic frames. The frame between two periodic frames only depends on its immediately previous frame. When the frame between two periodic frames appears error, the error will not propagate. Since periodic frame is more important than general P frame, more protection will be added on the periodic frame during video transmission.

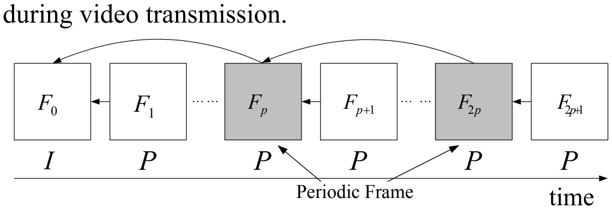


Figure 2. Periodic Frame

For most video coding standards, periodic frame introduces additional reference frame buffer in the encoder. Since most coding standards only support single reference frame, additional frame buffer is needed to store the periodic frames. We propose use the periodic frame concept in the new coding standard H.264. In this standard, five encoded frames can be used as reference frame. As long as the interval between two periodic frames does not exceed five, no additional reference frame buffer will be needed.

One disadvantage of periodic frame is that it costs more bits than general inter P frames. For most frames, the immediately previous frame is the best reference frame. For instance, multiple reference frame is supported in H.264, but more than 90% macroblocks will select the immediately previous frame as reference frame. Because the periodic frame uses the frame that is *p* frames away as reference frame, it costs more bits than ordinary P frame. To eliminate this disadvantage of periodic macroblock, we propose to use periodic macroblock instead of periodic frame. We encoded some macroblocks as periodic macroblocks rather than the whole frame in every *p*th frame, as shown in figure 3. The simulation results in part 3 indicate that the periodic macroblocks can significantly enhance the robustness of video with a small amount of bit overhead.

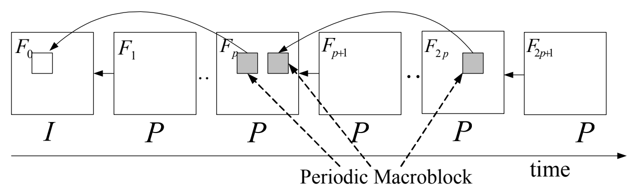


Figure 3. Periodic Macroblock

We use the distortion expectation of macroblocks in every *p* frame as the selection criteria of periodic macroblock. The distortion of each macroblock in the decoder can be presented in two parts. One part of the distortion is caused by quantization, as described in equation 1. f indicates the original pixel value in a macroblock *B*, $\tilde{f}$ is the reconstructed pixel in the encoder, and *n* is the frame index.

$$D_q = \sum_{x,y \in B} (f_n[x,y] - \tilde{f}_n[x,y])^2 \qquad [1]$$

Another part of distortion is caused by the transmission error. In the decoder of H.264, when a macroblock is lost or corrupted, the decoder replaces this macroblock with the co-location macroblock in immediately previous frame. Then the distortion made by transmission error can be written as equation 2.

$$D_t = \sum_{x,y \in B} (\tilde{f}_n[x,y] - \tilde{f}_{n-1}[x,y])^2 \qquad [2]$$

For the encoder, the distortion of each macroblock is a variable, since the encoder cannot make sure whether the macroblock can be received correctly or not. Then we use the expectation of distortion as the selection criteria of periodic macroblock. The expectation of distortion can be calculated by equation 3. ρ is the loss probability, it can be easily obtained through the feedback channel that is supported by most transmission protocols. The macroblocks that have maximum distortion will be selected as periodic macroblock.

$$D_{\exp} = (1-\rho)D_q + \rho D_t \quad [3]$$

The main purpose of error-resilient scheme is using little overhead to achieve good error resilience performance. The criteria we used to select the periodic macroblock can meet this requirement. Large quantization distortion indicates that it is not best match with any reference frame. When we encode this macroblock as periodic macroblock, compared with other macroblocks that have small quantization distortions, less additional bit overhead will be introduced. If the macroblock that has large distortion due to transmission error is lost, the video will appear obviously artifact. Generally more protection will be used to prevent the macroblock that has large distortion due to transmission error from loss. Since the periodic macroblock will have more protection during the transmission, selecting the macroblocks having large distortion due to transmission error as periodic macroblocks will enhance the robustness. The distortion expectation can incorporate both of quantization distortion and distortion due to transmission error. The computation of distortion expectation is not complicate, and it can be implemented in real-time video transmission.

Another problem should be considered about periodic macroblock is that how many macroblocks should be encoded as periodic macroblocks in every p frame. Since the periodic macroblock will cost more bit than general inter-macroblock, we propose to adjust the number of periodic macroblock according to the available bandwidth. The more bandwidth is available, the more macroblocks can be encoded as periodic macroblocks to achieve better error-resilience performance.

3. SIMULATION RESULT

We use a QCIF video sequence, Foreman, to conduct our simulation. The video is encoded and decoded by JM60, which is a standard codec of H.264. The frame structure in our simulation is IPPPP……, there are 49 P frames between two I frames. By change the quantization factor, the sequence can be encoded into different bitrates. To test the error resilient performance of proposed method, different macroblock loss rates are used in experiment. To enhance the robustness to data losses, the H.264 support flexible slice size and flexible macroblock ordering. So in our experiment we select the location of lost macroblock based on these properties.

In the standard encoder of H.264, the reference frame buffer stores 5 encoded frames as the reference frame for motion estimation. To avoid adding reference frame buffer, we select five frames as the interval distance. In other word, the periodic macroblocks in our simulation will use the fifth previously encoded frame as reference frame.

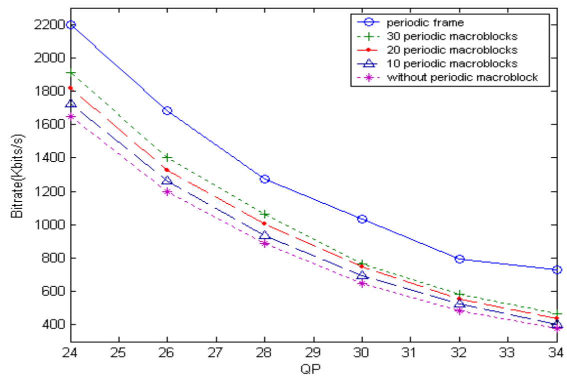
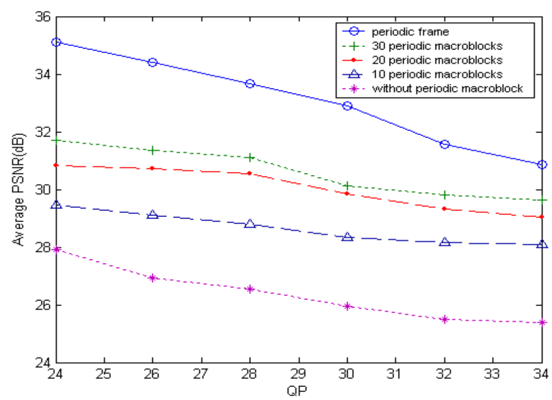
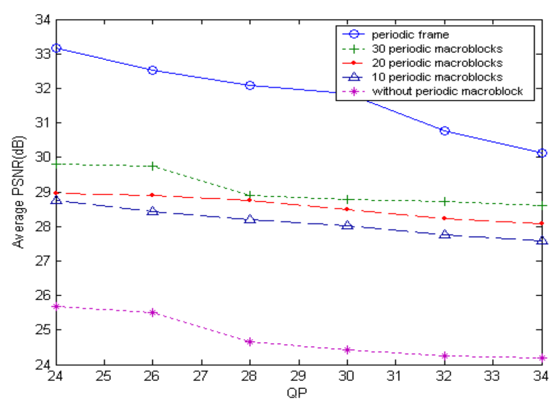


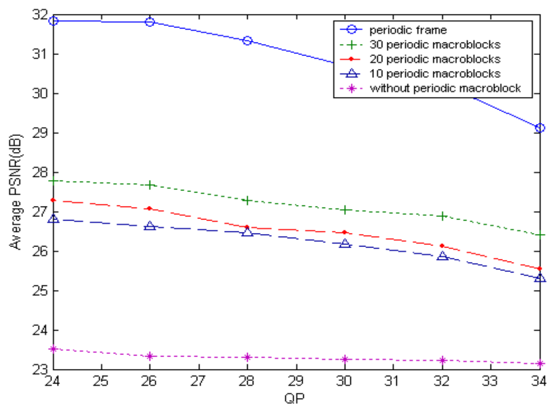
Figure 4. Bitrate Comparison



(a) 5% macroblocks lost



(b) 10% macroblocks lost



(c) 15% macroblocks lost

Figure 5. Comparison of PSNR

We compare the performance of proposed method with periodic frame. In the simulation, every five frame is encoded as periodic frame. The simulation result is shown in figure 4 and figure 5. Although the error-resilience performance of periodic frame is better, it cost much more bits than the proposed method. As shown in figure 4, when we encode the bit stream with periodic frame, which is equivalence to use 99 periodic macroblocks, the bitrate will increase 60% to 80%. The proposed method costs much less bitrate. When 10 macroblock is encoded as periodic macroblock in every five frame, the bitrate only increases approximately 5%, and PSNR improves about 2dB. When 30 macroblocks are encoded as periodic macroblocks, the bitrate increases about 15%. And the proposed method is more flexible than the periodic frame, since the encoder can adjust the number of periodic macroblock in every five frame according to the variation of bandwidth.

The simulation results prove that the video quality can be improved significantly by the proposed method. As presented in the figure 5, when 10 macroblocks are periodic macroblocks in every five frame, the PSNR of video can be improved about 2 dB with different macroblock loss rate. As the number of periodic macroblock increases, better PSNR improvement can be achieved. When there are 30 periodic macroblocks contained in every five frame, the PSNR can be improved more than 4 dB. The proposed method can be easily implemented in most practical situation on the current transmission channel.

4. CONCLUSION

In this paper, we present a content-based error-resilience scheme for H.264. Some macroblocks in every five frame are encoded as periodic macroblocks. That means these macroblocks will use the frame that is five frames away as the reference frame. Since multiple reference frame is supported in H.264, the proposed method will not introduce additional reference frame buffer to the encoder. The distortion expectation of macroblock in every five frame is used as the criteria to select periodic macroblocks. By using the proposed scheme, the error propagation between two frames that contain periodic macroblocks can be partially terminated. According to the simulation result, the video quality can be significantly improved by the periodic macroblocks with a small amount of bit overhead.

5. REFERENCES

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