An Error Resilient Video Coding Algorithm Combining FEC and WZ Technology over Error-prone Channel

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Abstract

Reliable video delivery has become one of the crucial issues in wireless video communications. Based on different error resilient property of forward error correction (FEC) and Wyner-Ziv (WZ), we propose a scheme which combines these two technologies. Experimental results demonstrate the scheme can possess their both advantages and have an improvement in the average peak signal to noise ratio (PSNR).

Keywords: Video compression coding stream; Error resilient transmission; WZ coding; FEC coding

1. Introduction

High compression video streams are very susceptible to transmission errors over error-prone channels. Almost all available video codec such as H.264/AVC, MPEG, follow the predictive coding paradigm which causes the problem of error propagation. In order to ensure the high quality of the video signals' transmission, people use error resilient methods such as redundant slices, flexible macro-block ordering, and multiple description coding [1] at the encoder. Moreover, at the decoder side, technologies of interpolation and estimation are used for data recovery or error concealment [2]. However, these methods achieve poor quality in the case of high packet loss. Another method is using forward error correction (FEC) [3].But if the error probability overwhelms the estimated probability of transmission errors, it results in rapid degradation of the picture quality, leading to the undesirable "cliff" effect.

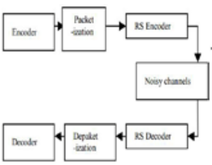
A new video coding technology -- distributed video coding (DVC)[4] has become increasingly popular in recent years. It is based on Slepian-Wolf's and Wyner-Ziv's information-theoretic results from the 1970s. In contrast to traditional coding standards, DVC are encoded independently but decoded jointly, which shifts the computational complexity from the encoder to decoder's side. Since no prediction loop exists at the encoder, the compression stream has an intrinsic robustness to error propagation. Therefore, many error resilient schemes [5-8] based on DVC have been proposed. Among them, systematic lossy error protection (SLEP) [6] turn out to be more classical, it avoids cliff effect that FEC brings at high packets loss but has poor performance when the packets loss is low.

In the paper, we propose an error resilient scheme combining FEC and WZ, which possesses the benefits of the two technologies. It has been proved that the scheme has a better performance in terms of visual quality.

2. Principles of FEC and WZ

Figure 1 shows the principle block diagram of FEC. If noisy level is within the correction capability of FEC, we can use RS decoding to recover the lost information. Otherwise, the entire RS coding will be discarded. Theoretically, we can send a sufficient number of parity bits to increase the RS error correction capability, but it will lead to huge bandwidth usage. When the error probability becomes high and the number of them overwhelms the RS code's correction ability, this will severely impact the reconstructed quality of frames.

The concept of WZ coding based on H.264/AVC is illustrated in Fig.2. Video to be encoded is divided into two parts: the primary bit-stream and the redundant bit-stream. The primary part are encoded using conventional H.264/AVC standard, while redundant part keeps the same header information, e.g., coding modes, motion vectors, and reference frames, etc., as the primary part, but with coarser quantization. WZ coding is implemented on the redundant bit-stream for error correction. Only when the channel errors occur, is WZ decoding invoked.



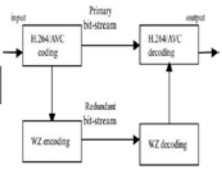


Fig. 1: FEC   Figure 2:WZ

3. Proposed scheme combining FEC and WZ

Our proposed system is shown in Fig.2.After H.264 coding, the primary bit-stream is directly conveyed to the decoder over the channel, while the redundant bit-stream is divided into two parts: one is WZ coding which use RS coding with coarse quantization; the other use FEC coding in the event of low packet loss. In order to improve the transmission efficiency, only the parity check bits generated by RS coding are transmitted to the decoder to correct transmission errors. At the decoder, the primary bit-stream will be re-quantized to serve as the side information for RS coding. What's more, error concealment will be used to enhance the system performance.

Without transmission errors, WZ and FEC parts will not be used, video can be reconstructed bit-by-bit at the decoder. Once the errors occur and at high packet loss, system will automatically select WZ coding pathways; on the contrary, when the packet loss rate is low, it will choose FEC pathway. The quality of reconstructed pictures depends on the quantization step size as well as the strength of RS code. The following operations are performed:

- WZ coding: The RS code over $GF(2^8)$, together with coarse quantization compose the WZ coding of redundant description.
- FEC coding: We also use RS code , whose parity part changes according to bit error rates of the wireless channel.
- Decoding: including primary bit-stream decoding, WZ decoding and FEC decoding. Coarse quantization at the decoder is used to generate side information for WZ decoding.
- Error concealment: Macro-blocks which FEC or WZ cannot correct are sequentially reconstructed by filling them with a weighted set of templates extracted from the available neighbourhood

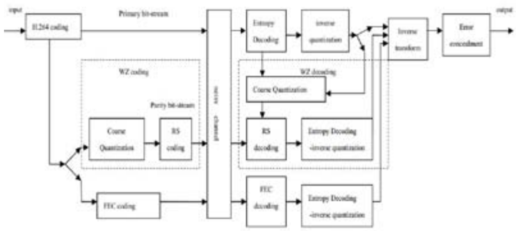


Fig.2: Proposed system block diagram

Bit-rate allocation between primary and the two error resilient bit-streams are based on the principle of end-to-end distortion minimum. According to [12], the end-to-end distortion in the nth frame evolved into:

$$D_n^{EE} = (1-p)D_n^{Ep} + pp_{WZ}D_n^{WZ} + pp_{FEC}D_n^{FEC} + p(1-p_{WZ}-p_{FEC})D_n^{EC} \quad (1)$$

$$p_\alpha = \sum_{m=K}^{m=N-1} \binom{N-1}{m} (1-p)^m p^{N-1-m} \quad (2)$$

index of α can be WZ or FEC, p_α indicates the probability that WZ or FEC can decode successfully. p denotes the error rate of video transmission, D_n^{Ep} 、 D_n^{WZ} 、 D_n^{FEC} 、 D_n^{EC} are respectively the mean square error (MSE) distortion of primary, WZ, FEC, and error concealment. In equation (2), K denotes the information bit number, N is the code length.

The rate distortion of primary bit-stream can be denoted by

$$R_p = C_1 \frac{MAD}{Q} + C_2 \frac{MAD}{Q^2} \quad (3)$$

where C_1 , C_2 indicate the update coefficients, Q is the quantization step size, MAD is the abbreviation of mean average distortion. From [9] we know the relationship between the MSE distortion and the WZ bit rate

$$D_{WZ} = E(X_n^i - \hat{X}_n^i)^2 = D_{WZ0} + \frac{\theta_{WZ}}{R_{WZ} - R_{WZ0}} \quad (4)$$

where D_{WZ0} 、 θ_{WZ} 、 R_{WZ0} are related to the sequence being coded, encoding parameters, mode decisions etc.

When to use FEC depends on the bit error rate of the channel. In our proposed scheme, FEC will be selected when the bit error is lower than about 5%. Connecting with channel bandwidth, the coding bit rate will be determined.

4. Simulations results

Our experiments are simulated on the testing platform of JM11.We compare the average PSNR of the sequence of Football.sif, Foreman.cif at different packet loss probability (3% 、 5% 、 10% 、 20%), respectively with using FEC and WZ. In our proposed scheme of WZ part, the redundant slices are encoded at 25% of the bit rate of the primary slices. In group of (a) , the WZ bit rate is 10% of the bit rate of primary slices; for FEC part, the primary description is identical to the redundant description, and the parity bit rate generated by the Reed–Solomon encoder is 10% of the bit rate of the primary slices. For comparison, we increase the parity bit rate from 10% to 20% of both FEC and WZ in group of (b).

It can be seen from Fig.3 and Fig.4 that the proposed scheme combines the advantages of WZ and FEC: at low packet loss about 5%, the average PSNR of our scheme is higher than WZ, while packet loss increases, the average PSNR of proposed scheme is higher than that of FEC.

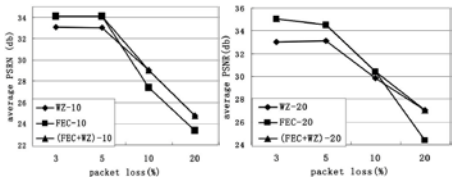


Fig.3:（a） Foreman CIF（b） Foreman CIF

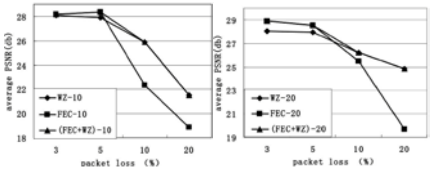


Fig .4:（a）Football SIF （b）Football SIF

Comparing groups of (a) and (b), we also found that at low error bit rate, robustness increases when parity bit rate is increased from 10% to 20%.

5. Conclusion

In this paper, we propose an error resilience scheme that combines two error resilient technologies: WZ and FEC. If there's no error, neither of them will be used. Once errors occur, system can automatically select the proper coding (WZ or FEC) according to the bit error rate. Simulations revealed that proposed system can effectively improve the error resilient performance comparing to use them separately. What's more, it could be better if we solve the problem of bit- rate allocation problem. Thus how to allocate the bit rate between classic bit-stream and error resilience bit-streams, as well as between WZ bit-stream and FEC bit-stream to make the system end-to-end distortion minimum will be the focus of our future research.

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