Improving The Robustness of The MPEG4 Wavelet Transform Image Coder

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Abstract

This paper proposes schemes to improve the robustness of the ISO/IEC JTC1 Recommended MPEG-4 still image (wavelet) coder, particularly for operation in wireless mobile environments. Combined source and channel coding is used to selectively protect error sensitive bits in the encoded bitstream. The proposed schemes emphasise on protecting the integrity of DC coefficients that contain more than 90% of the image energy. The employed schemes in this study ensure that the system can operate in random error prone environments of BER up to 10^{-3}.

1. Introduction

In the ISO/IEC JTC1 MPEG-4 standard, a wavelet transform coder has been adopted as the still image coder to achieve high compression, good image quality, while also supporting progressive image transmission [1]. The lowest resolution subband of the Y, U, and V images (termed the DC components) are coded separately using DPCM followed by variable length coding (VLC). The other sub-bands (termed the AC components) are coded using embedded zero-tree coding coupled with VLC.

For reliable and stable operation of this still image coder, a good quality channel is assumed. This unfortunately is not the case for mobile radio channels where multipath fading and co-channel interference act as the main impediments. The use of VLC coding, in particular, is highly susceptible to channel errors leading to loss of synchronisation resulting in incomplete decoding at the receiver.

Various methods have been proposed for portable still image transfer. Brewster, et al [2] proposed the use of ARQ coupled with fixed length coding using forward error correction (FEC) and interleaving for a DCT based image coder. Westerink, et al, [3] proposed an unequal error protection scheme for wireless transmission of subband coded images, where protection between the more significant and the less significant bits is distinguished with the use of different FECs.

More recently, a packetization approach [4] has been proposed for the MPEG-4 still image coder in order to improve the error resiliency. In this technique, the wavelet coefficients are segregated into different packets and additional overhead information is introduced in order to facilitate such segregation. However, when errors are injected using the NTT DoCoMo simulator [5], the approach results in a reconstructed Y-PSNR that is less than 50% of the original errorless reconstructed Y-PSNR.

Our contribution focuses on making the MPEG-4 still image coder robust against the adversity of channel errors. We assume the use of a standard MPEG-4 still image source encoder [1] at the transmitter and decoder at the receiver. Baseband post-processing of the bitstream output of the MPEG-4 encoder is carried out prior to transmission. This is followed by pre-processing of the received modified bitstream to recover an MPEG-4 still image compliant bitstream before feeding it to a standard decoder.

2. System Description

Figures 1 and 2 show block diagrams of the proposed robust still image encoder and decoder respectively. The header information bits pertaining to the DC coefficients are excluded from errors. The MPEG-4 still image encoder has been modified such that fixed length coding (instead of VLC as originally used) is employed for the DC coefficients while VLC is maintained for the AC coefficients of the YUV images. Here, our primary focus is on protecting the integrity of the DC coefficients. As the DC coefficients contain more than 90% of the image energy, they will cause the most severe degradation in PSNR if the compressed bitstream is subjected to errors.

The error-protection of the AC information is part of our on-going work.

In the proposed schemes, forward error control (FEC) is applied to the DC coefficients. The FEC coded bits are then multiplexed together and input to an interleaver. The interleaver provides time diversity in randomising bit error bursts that may occur in wireless channels. A (198 x 15) interleaver matrix is used. Finally, the enhanced bitstream is subject to errors injected by the NTT DoCoMo simulator [5]. Figure 2 shows the proposed receiver. The received bitstream is de-interleaved and error correction and detection is performed. If an incomplete decoding occurs for the DC U or V coefficients, concealment is performed. A frequency distribution is maintained at the receiver end to compute the mode value among the DC U or V coefficients. In the case of an uncorrectable error pattern, which results in incomplete decoding, concealment is achieved by substituting all the DC U or V coefficient values with their respective modal values.

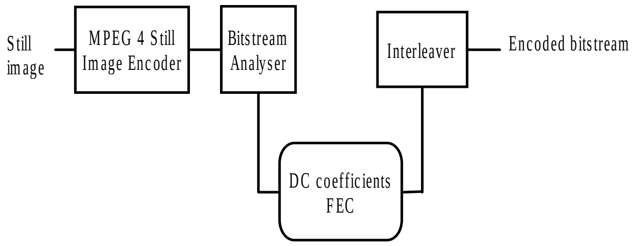

Figure 1: Proposed Encoding Scheme

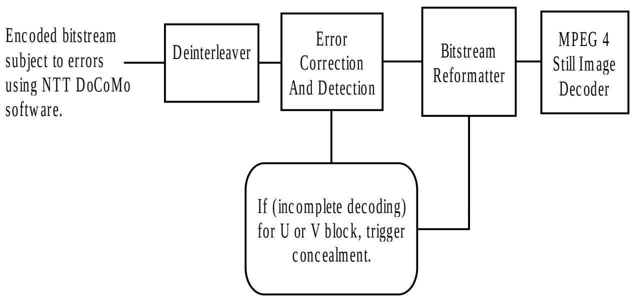

Figure 2: Proposed Decoding Scheme

3. Forward Error Control

Bose Chaudhuri Hocquenhem (BCH) block code [6] has been considered as the FEC tool since it is simple and effective. BCH (15,7,2) and BCH (31,21,2) are chosen to protect the integrity of the header and coefficient bits. Unequal FEC protection is applied with BCH (15,7,2) used for the DC Y coefficients, while BCH (31,21,2) is used to protect the DC UV subband coefficients. The Berkelamp Massey iterative decoding is used at the decoder to correct for any errors. The correction algorithm will fail if an uncorrectable error pattern occurs. This gives rise to incomplete decoding which can be used to trigger the concealment technique.

With the inclusion of the BCH (15,7,2) for the DC Y coefficients, there is a small increase in the number of bits required to code the image. However, it is also shown in the experiment that the huge improvement in the PSNR of the recovered image when subjected to errors more than justify the increase in the number of bits.

3.1. Error Concealment

It has been observed that the DC coefficients in the chrominance blocks has low variance and high spatial cross-correlation as compared to the luminance block. Concealment can be achieved by replacing all the coefficients in the chrominance blocks with their respective modal value. This ensures uniformity in the resulting image.

4. Results

Simulations are performed by using the NTT DoCoMo error simulator [4] to inject random or burst errors into the compressed bitstream. For random errors, the bit error rate (BER) is kept at 10^{-3} and the bitrate at 24kbps. In the case of burst errors, the BER is 10^{-3}, the bitrate at 24kbps with burst length and BER at burst duration kept at 1ms and 0.5 respectively. Numerous seed values were taken and the average values together with the standard deviations are compiled (see Tables 2-8).

Table 1 shows the PSNRs of the 2 decompressed CIF test images, namely *News* and *Funfair*, using the original MPEG-4 still image coder [4] and assuming error-free condition. Here, a QMF 9-tap filter and a 3-level decomposition have been used. Table 2 shows the results when random errors has been injected into the fixed length DC coefficients of the 2 CIF images.

	Image	
	News	**Funfair**
Bits	179072	258448
PSNR (Y)	40.34 dB	40.77 dB
PSNR (U)	45.39 dB	41.89 dB
PSNR (V)	45.96 dB	41.88 dB

Table 1: PSNR results under error-free condition

	Image	
	News	Funfair
BER (random error)	$1x10^{-3}$	$1x10^{-3}$
PSNR (Y)	10.25 dB	9.58 dB
PSNR (U)	7.31 dB	10.04 dB
PSNR (V)	6.15 dB	7.13 dB

Table 2: PSNR results under random errors.

Table 3 shows the results produced by our proposed scheme for the 2 corresponding CIF images when random errors are injected. The unequal FEC and time diversity approach results in perfect decoding for the Y subband coefficients only. The UV subband coefficients experience incomplete decoding.

	Image	
	News	Funfair
BER (random error)	$1x10^{-3}$	$1x10^{-3}$
PSNR with concealment + BCH (31,21,2) + interleaving (Y)	40.34 dB	40.77 dB
PSNR with concealment + BCH (31,21,2) + interleaving (U)	22.41 dB	31.26 dB
PSNR with concealment + BCH (31,21,2) + interleaving (V)	27.59 dB	26.86 dB

Table 3: PSNR results with BCH(31,21,2), interleaving and error concealment.

On average 3 incomplete decoding errors were flagged for the tested images for the U and V bands when subjected to random errors. Concealment was triggered for the chrominance bands. The level of improvement offered by the concealment was inversely proportional to the variance between the UV block coefficients. The results in Table 3 substantiate this observation.

For burst errors, on average 11 incomplete decoding errors are flagged. Tables 4 and 5 show the results produced by the original basic system with error resilience control and our proposed scheme, respectively, for burst errors. The FEC, time diversity and concealment allow for good U and V subband reproduction at the receiver end. However, insufficient interleaver depth gives rise to the poorer performance for the luminance subband.

	Image	
	News	Funfair
BER (burst error 1ms)	$1x10^{-3}$	$1x10^{-3}$
PSNR (Y)	Undec.	Undec.
PSNR (U)	6.10 dB	6.01 dB
PSNR (V)	6.12 dB	4.19 dB

Table 4: PSNR results under burst errors (Undec. = Undecodable)

	Image	
	News	Funfair
BER (burst error 1ms)	$1x10^{-3}$	$1x10^{-3}$
PSNR with BCH (15,7,2) + interleaving (Y)	14.93 dB	10.87 dB
PSNR with concealment + BCH (31,21,2) + interleaving (U)	22.41 dB	31.26 dB
PSNR with concealment + BCH (31,21,2) + interleaving (V)	27.59 dB	26.86 dB

Table 5: PSNR results (Y) with BCH (15,7,2).

In order to show the effects of the concealment method, an experiment is performed by purposely disabling the interleaver so that the concealment process will be explicitly activated. One of the test images, the *News* image, shown in Figure 3(a) is used and this image is subjected to random error with a BER of 10^{-3}. Then, the compressed bitstream is decoded using BCH protection but with no interleaving and the resultant decoded image is shown in Figure 3(b). This figure shows that the colour components are wrong due to the random errors. Figure 3(c) shows that by activating the concealment process, reasonably good decoded image can be obtained.

Similarly, another experiment is conducted by subjecting the compressed bitstream to burst errors. One of the test image being used is the *Funfair* image shown in Figure 4(a). The resultant decoded image using BCH and interleaving (but without concealment process) is shown in Figure 4(b). Due to the insufficient interleaver depth and the fact that BCH(31,21,2) is being used for the UV components, the decoded colour components are wrong. Figure 3(c) shows that by activating the concealment process, reasonably good decoded image can be obtained. It can be seen that the PSNR for the U component has improved.

Fig 3(a): Original *News* Image
PSNR Y: 40.34 dB, PSNR U: 45.39 dB, PSNR V: 45.96 dB

Fig 3(b): ***News*** **Image with Random error BER 10^{-3} (with BCH protection but no interleaving)**
PSNR Y: 40.34 dB, PSNR U: 9.26 dB, PSNR V: 44.96 dB

Fig 3(c): ***News*** **Image with Random error BER 10^{-3} (with BCH protection, no interleaving but Concealment activated)**
PSNR Y: 40.34 dB, PSNR U: 22.42 dB, PSNR V: 44.96 dB

Fig 4(a): Original ***Funfair*** **Image**
PSNR Y: 40.77 dB, PSNR U: 41.89 dB, PSNR V: 41.88 dB

Fig 4(b): ***Funfair*** **with Y and U block subjected to burst error (with BCH + interleaving but no concealment)**
PSNR Y: 38.13 dB, PSNR U: 10.21 dB, PSNR V: 41.88 dB

Fig 4(c): ***Funfair*** **with Y and U block subjected to burst error (with BCH + interleaving + concealment)**
PSNR Y: 38.13 dB, PSNR U: 31.26 dB PSNR V: 41.88 dB

5. Conclusion

We have proposed a source matched portable still image communication system to enhance the robustness of the MPEG-4 still image coder. Various approaches are adopted including:

- Bit interleaving to randomize bit errors
- Source matched FEC to counter random errors
- Error concealment strategy for the U and V blocks of the still image
- Diversity reception to combat fading

Through these combined approaches, we are able to extend the robustness of the MPEG-4 still image coder to withstand random error environment of BER 10^{-3}.

6. References

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