Error Resilient Coding Based on Reversible Data Hiding and Redundant Slice

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***Abstract*—Compressed video streams are sensitive to errors and losses when transmitted over wireless error-prone channels. In this paper, we propose an Error Resilient (ER) scheme based on Reversible Data Hiding (RDH) and Redundant Slice (RDH-RS). Reversible data hiding is quite effective in unequal protection and can provide satisfactory protection to vital information, while redundant slice works well in protecting mass important data. Our scheme exploits both advantages. At the encoder side, we apply RS protection to odd frames, and embed vital data, the motion vectors (MV) of even frames, into the redundant slice of odd frames by bidirectional-RDH method, thus providing protection to even frames. If an MV of an odd frame cannot be correctly decoded at the decoder side, the redundant slice of odd frame will be utilized for error concealment. If the lost MV belong to an even frame's macroblock (MB), then the MV will be retrieved from the redundant slice of prior odd frame and help restoration. As our data hiding method is reversible, no extra visual quality degradation will happen, and the computational burden is quite low. Experimental results demonstrate that RDH-RS method can provide much better protection to fragile compressed video when compared with the previous arts.**

Keywords-Error resilient;Reversible Data Hiding;Redundant Slice; Error concealment

I. INTRODUCTION

H.264/AVC video coding standard is designed by ITU-T Video Coding Experts Group and ISO/IEC Moving Pictures Experts Group, and its purpose is to achieve high compression ratio as well as satisfactory visual quality by reducing the spatial and temporal redundancy. The sensitivity of video bit streams to errors lead to the fact that video visual quality will suffer from serious degradation when transmitted over wireless error-prone channel. Common degradations include transmission packet loss and transmission error caused by fading in wireless channels[3].

To handle these problems and enhance the robustness of video bit streams to errors, researchers have proposed many error resilience (ER) and error concealment (EC) techniques [1-4,6] in the past decades. Error resilience techniques follow the idea of error correction coding, and add some redundant information into the bit streams at the encoder side in Fig.1. For example, H.264 has incorporated Redundant Slice (RS) technique. Important region of a picture will be encoded twice, so if the primary slice is contaminated during transmission and cannot be correctly decoded, the redundant slice will be helpful. The basic idea of ER is to enhance the robustness of compressed bit streams against packet loss and error, with the cost of reduced coding efficiency [3][4][6].Error concealment techniques handle the problem in another way. No redundant information is added into the bit streams at the encoder side. After receiving the bit streams, the decoder try to reconstruct the image sequence. If an error is found, the decoder will try to "conceal" the error. For example, if a block cannot be correctly decoded, it can be estimated by its neighboring blocks(the neighboring blocks should be correctly decoded, of course). The estimation will lead to blur, but large area of error is avoided. Generally, error concealment is the last shield, but obviously, its protection is quite limited. Primary protection should be undertaken by error resilient coding.

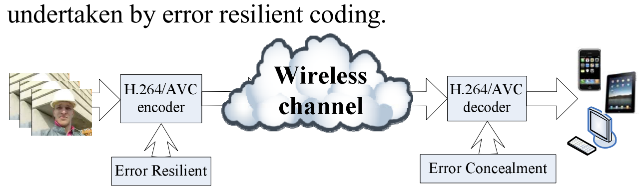

Fig.1 bit streams over wireless error-prone channels

Many error resilient methods have been proposed since it was first introduced. Most methods add parity information, or another copy of important regions, to the bit streams. Recently, a new idea of combing error resilient coding and data hiding emerged.

Chen and Leung [1] proposed a data hiding based (DH-based) method for video error concealment, which has little computation cost at the decoder side. In their method, motion estimation is first implemented between two consecutive I-frames, and the motion vectors, as the redundant information, are embedded into quantized DCT (QDCT) coefficients. At the decoder side, the embedded motion vectors are extracted and they can help exactly find the reference MBs and recover the corrupted MBs. However, the data hiding process changed the quantized DCT coefficients permanently, and this leads to extra visual quality degradation. Chung et al[2] improves their method by using reversible data hiding. In their method, first increase positive QDCT coefficients by one, if the scanned bit of MV is zero, the corresponding zero QDCT coefficient remains its value. Otherwise, the corresponding zero QDCT coefficient is changed to one[2].

However, we should realize that the capacity of DH-based method is restricted, which leads to limited protection. Generally speaking, this approach is used to protect the emphasis information such as Synchronization information and MVs etc.As for redundant slices technique in H.264/AVC, which protect the frame information equally. However, there are two drawbacks of this method. First it ignores the priority of important regions; second, the size of bit streams increases significantly. This observation inspires

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us to design a reversible data hiding (RDH) scheme to embed the MVs of primary slices into the MVs of front redundant slices. Compared with DH-based method, the proposed scheme can protect more information or regions. Compared with using only redundant slices, our method not only reduces bit streams size remarkably, but also has no influence on primary slices. Besides, the decode program reading MVs form Network Abstraction Layer (NAL) is earlier than QDCT coefficients. Thus, our method is computational cheaper while embedding information into MVs of redundant slices at the decoder side, and it is suitable for environments that computation resources are limited.

The paper is organized as follows. Section 2 describes the proposed Reversible Data Hiding and Redundant Slice (RDH-RS) error concealment algorithm using reversible data hiding and redundant slices. The simulations done using the proposed RDH-RS technique and the obtained results are presented in Section 3. In Section 4, conclusions are briefly drawn based on the results.

II. REVERSIBLE DATA HIDING AND REDUNDANT SLICE (RDH-RS) METHOD

In this section, the proposed scheme is described in five aspects as follows.

A. Redundant Slice Scheme

Redundant Slices is a new feature of H.264/AVC coding standard.A redundant slice is a coded additional representation of a primary slice. The parameters (1) used for encoding the redundant slices may differ from those used for the primary slices, but they should have no visual discrepancy between the two representations[5]. We set the redundant parameters as follow

$$QP_{redundant} = QP_{primary} + qp \qquad (1).$$

Redundant slices even do not have to cover the entire region represented by the primary pictures. At the decoder side, when the primary slices are lost or cannot be correctly decoded, redundant slices can be utilized to improve the decoded video quality. If the primary slices can be correctly decoded, the redundant slices will be abandoned.

In this section, we design a new strategy to add redundant slice. If frame number is odd, it will generate a redundant slice. Otherwise, that is the frame number is even, it will not add redundant slice. As Fig.2 show, suppose that the number of current frame N is odd, and thus we will embed the MVs of N+1 primary slice into the MVs of N redundant slice ,and so on.

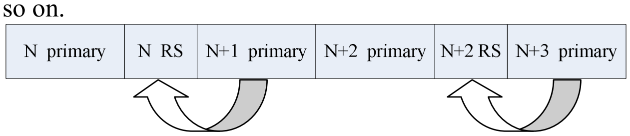

Fig.2 RS location and embed idea

B. Selection Motion vectors

Obviously, if we embed all MVs information of primary into previous redundant slice, it will bring computational complexity and it's not necessary.

Generally speaking, the motion object is usually locate at the center of the current frame as show in Fig3.This observation inspires us to select the MVs locate at the center as the protect information.

$$A = W_{reg} \times H_{reg} / size(MB) \qquad (2)$$

Where A is total number of MBs. W_{reg} ,and H_{reg} are,respectively, the width and length of selection regions.

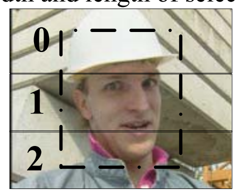

Fig.3 "face" locate at the center of the frame

In paper[1],the motion vector is within the range of 15 pixels and its precision is half pixel. Consequently, the total number of the information bits to represent the MV of one MB is

$$L_{DH} = 2\times(\log_2 \max(2\times 15)+1) = 12 \qquad (3)$$

In our method, we modify L_{DH} to L_{RDH_RS} as follow

$$L_{RDH\_RS} = 2\times(\lceil \log_2(2\times R_{range}+1) \rceil + 1) + L_p \qquad (4)$$

where R_{range} is the search range, L_p is number of parity bit, and is using to check the Correctness of L_{RDH_RS} .In our method ,we set R_{range} =15,and L_p =1.

C. Bidirectional-RDH method

The selected MVs are converted into a binary sequence before we embedded it into the N-th redundant slice's MVs, denoted as:

$$I = \{b_1 ... b_n ... b_L\}, 1 \le n \le L$$

As shown in Fig.4, (a) is the Original MVs' distribution, acted as the cover sequence.

Fig.4 (b) shows the embedding process by modify the "0"-value of the cover sequence:

- Firstly, all the non-zero values of the cover are shifted one step away from the "0"-value, so the "-1" and "1" value positions are available for embedding.
- Secondly, if b_n is 0, the "0"-value of the cover will keep unchanged. Otherwise the b_{n+1} will be scanned:
  - if b_n b_{n+1}=10, the "0"-value of the cover will be changed into "1";
  - if b_n b_{n+1}=11, the "0"-value of the cover will be changed into "-1".

More generally, if the modified value of the cover sequence extends similarly from "0" to "-1", "1" and other non-zero values, as shown in Fig.4(c), the embedding capacity could be improved effectively.

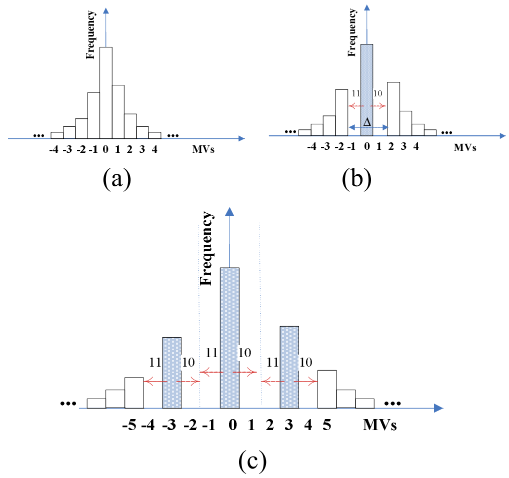

Fig.4 show embedding process.
(a)Original MVs distribution.(b) Shift positive coefficients to right by one, and Shift negative to left by one, the cover sequence is "0". (c) the cover sequence is "-1,0,1".

Here, we summarize the general embedding formula as show in (5) and (6).The first, all larger than l-value MVs are shifted the right position by $(l+1/2)\times\Delta$,while all smaller than $-l$-value MVs are shifted to the left position by $-(l+1/2)\times\Delta$,where Δ denotes the shift step. Assuming the original MVs set of M-th MB in the N-th frame is $F_{N,M}$,and then

$$\widehat{F}_{N,M}=\begin{cases} F_{N,M}+(l+1/2)\times\Delta & F_{N,M}>l \\ F_{N,M}-(l+1/2)\times\Delta & F_{N,M}<-l \\ F_{N,M} & otherwise \end{cases} \quad (5).$$

Where, Δ denotes the shift step , l is the value of MV. For example, in the Fig.4(b) l=0, Δ=2,and in (c) l=1, Δ=2.

The process of embedding these information sequences into MVs is performed by

$$\widetilde{F}_{N,M}=\begin{cases} \widehat{F}_{N,M}\times(1+\Delta)+\Delta/2 & -l\le\widehat{F}_{N,M}\le l, b_nb_{n+1}=10 \\ \widehat{F}_{N,M}\times(1+\Delta) & -l\le\widehat{F}_{N,M}\le l, b_n=0 \\ \widehat{F}_{N,M}\times(1+\Delta)-\Delta/2 & -l\le\widehat{F}_{N,M}\le l, b_nb_{n+1}=11 \\ \widehat{F}_{N,M} & \widehat{F}_{N,M}>l, \widehat{F}_{N,M}<-l \end{cases} \quad (6)$$

Up to now, the information sequence have been stored in $\widehat{F}_{N,M}$.

D. Retrieval data for Concealment

By extracting information sequence b_n from MVs at the decoder side, we reconstruct the MVs. The retrieval process can be interpreted as

$$b=\begin{cases} b_nb_{n+1}=10 & \widetilde{F}_{N,M}=\widehat{F}_{N,M}\times(1+\Delta)+\Delta/2 \\ b_n=0 & \widetilde{F}_{N,M}=\widehat{F}_{N,M}\times(1+\Delta) \\ b_nb_{n+1}=11 & \widetilde{F}_{N,M}=\widehat{F}_{N,M}\times(1+\Delta)-\Delta/2 \end{cases} \quad (7),$$

where $-l\le\widehat{F}_{N,M}\le l$. b_n is the information sequence retrieved at the decoder.

Further, we can recover the original MVs,by performing

$$F_{N,M}=\begin{cases} \widetilde{F}_{N,M}-(l+1/2)\times\Delta & \widetilde{F}_{N,M}>(3l/2+1/2)\times\Delta \\ \widetilde{F}_{N,M}+(l+1/2)\times\Delta & \widetilde{F}_{N,M}<-(3l/2+1/2)\times\Delta \\ (\widetilde{F}_{N,M}+k\times\frac{\Delta}{2})/(1+\Delta) & otherwise \end{cases} \quad (8),$$

Where $k=\begin{cases} -1 & b_nb_{n+1}=10 \\ 0 & b_n=0 \\ 1 & b_nb_{n+1}=11 \end{cases}$.

Obviously, the perturbed MVs can be recovered completely by (7) and (8),as show in Fig.5. So our proposed bidirectional Reversible Data Hiding and Redundant Slice (RDH-RS) method for H.264/AVC has no quality degradation.

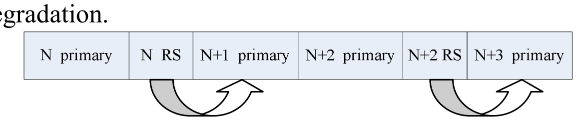

Fig.5 using information for error concealment

E. Capacity Analysis

Now we discuss RDH-RS method capacity. As show in Fig.6, one MB may be portioned into 16x8, 8x16 , 8x8.and 8x8 partition is further partitioned into partitions of 8x4, 4x8, or 4x4 samples.

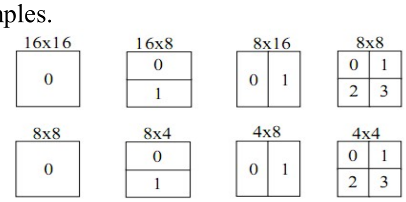

Fig.6 Segmentations of the MB and 8x8 partitions

So capacity bound is

$$2\frac{W\times H}{size(MB)}m_{\min}t\le 2\sum_{i=0}^{\frac{W\times H}{size(MB)}} m_it\le 2\frac{W\times H}{size(MB)}m_{\max}t \quad (9).$$

Where, W and H denotes the width and height of frame. $size(MB)$ represents the size of one MB. m_i , $m_{\max}$ and $m_{\min}$ respectively denotes the i-th MB divided into m blocks , Maximum number and Minimum number . t represents average embed bits per motion vector. So the Maximum bits of embedding into one 176 × 144 (352 × 288)frame can reach 1782(7128) bits.

III. THE EXPERIMEN AND SOME ANALYSIS

In this section, the proposed RDH-RS error resilient algorithms have been integrated into the Joint Model (JM) version 8.6 of H.264/AVC. We compare the performance between our proposed method and the RDH method proposed by Chung and Huang[2] for intra-frame error concealment in H.264/AVC sequences. We implemented these methods on the computer with Intel Pentium 4 CPU 3.00GHz and 1GB RAM. The program developing environment is Visual C++ 2008 based on Microsoft Windows XP operating system. The "rtpdump" project is used to implement the packet loss. In our experiment, we set A=16, Δ=2, l=1 etc.

The frame GOP structure is set to IPPPP. Setting five different redundant slices quantization parameters $QP_{redundant}$ 34, 38, 42, 46, and 50,are considered while encoding the Redundant Slices. In order to analysis the relations between PSNR and bit rate increment of RDH method, we set encode parameters "IntraPeriod = 6,7,8".

TABLE I. TEST VIDEO SEQUENCES

Video sequence	Size
Foreman	176×144
Carphone	176×144
Silent	352×288
Mobile	352×288

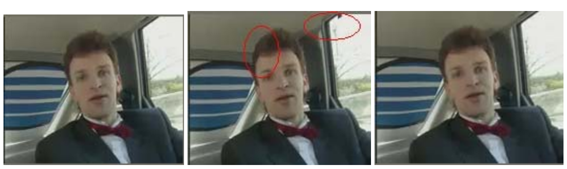

Fig.7 Concealed results of Carphone sequence with 10% loss.(a)original .(b)recovered by RDH[2].(c) recovered by OUR method(RDH-RS).

TABLE II. PSNRS OF RECOVERED SEQUENCES FOR 10%LOSS

Methods	Video Sequences			
	Foreman	*Carphone*	*Silent*	*Mobile*
RDH[2]	43.59	42.98	36.99	34.79
RDH-RS	**45.18**	**45.46**	**39.11**	**35.50**

We compare the performance of our algorithm to the RDH method [2].Tables2 presents the quantitative results. The proposed method is found to have better performance.Figs.7 shows the "Carphone" sequences with a 20% loss. It can be seen through subjective inspection that the proposed method can achieve the better results.Fig.8 shows the relations between PSNR and average bit rate increment. Compared with RDH[2] method, our scheme can get higher PSNR with less bit rate increment

IV. CONCLUSION

In this paper, we introduce a new low complexity yet effective approach RDH-RS for error concealment. At the encoder side, the proposed method embeds MVs of primary into previous redundant slice by modify its MVs, and the corrupted MBs can be recovered completely. Compared with DH-based method, The proposed scheme can protect more information. Compared with using only redundant slices, our method not only reduces bit streams size remarkably, but also has no influence on primary slices. The proposed method reduce the computation burden at decoder .Computer simulations show that our error concealment can be improved significantly in terms of both PSNR and subjective picture quality.

ACKNOWLEDGMENT

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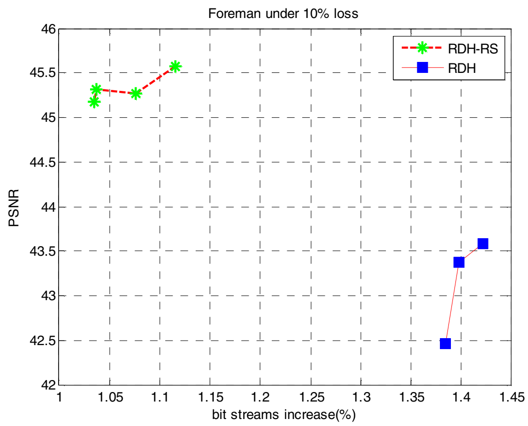
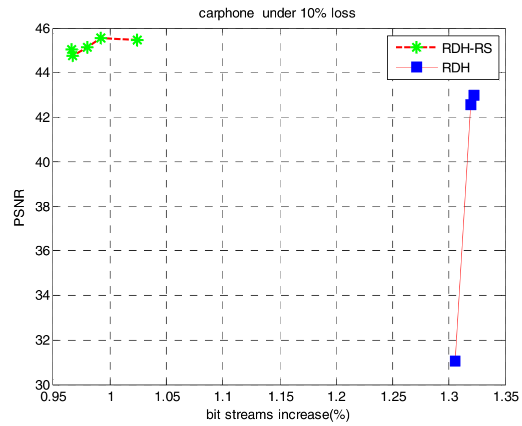


(a)



(b)

Fig.8 Packet loss rate is 10%, the PSNR loss and the bit rate increment of RDH[2] and RDH-RS performance. (a)Foreman.(b)Carphone.