Base Layer Constrained Error Concealment Solutions for Robust SHVC Video Transmission

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***Abstract*—Considering for a powerful scalable video coding engine, not only in error-free but also in error-prone environment, this paper proposes three error concealment (EC) solutions to fully exploit the base layer (BL) available information. While the first EC solution employs the BL reconstructed texture, the second EC solution employs the BL motion vector information to conceal the lost frame/block. In the third solution, we propose a hybrid EC scheme, which adaptively combines the BL texture and BL motion information to conceal the lost frame/block. The proposed error concealment solutions are integrated into the decoder and adaptively performed along with the coding structure of the scalable high efficiency video coding (SHVC) standard. Experiments conducted for a rich set of test sequences and conditions have shown the advances of the proposed EC solutions, notably with around 10 dB concealed frame quality improvement when compared to the conventional frame copying approach.**

***Keywords*—** *SHVC standard; Error concealment, Frame loss; hybrid approach*

I. Introduction

The heterogeneity of networks, terminals and transmission environments have been asking for a more powerful scalable video coding engine which works smoothly not only in the error-free but also in the error-prone environments. In the practical transmission environment, the network congestion may affect to the latency of video transmission and if this problem occurs regularly, the video quality may be severely degraded. To address this problem, error concealment process has been proposed for the previous Scalable Video Coding (SVC) standard [1] in which the available information from base and enhancement layers are employed to conceal the loss of frame or block.

Scalable High Efficiency Video Coding (SHVC) standard has recently been released in which the layered coding structure is again adopted [2]. The SHVC scheme typically consists of a base layer (BL) and one or several enhancement layers (ELs). Video sequences are compressed in each layer with the coding structure and coding tools extended from the High Efficiency Video Coding (HEVC) standard [3]. The use of multiple layers approach makes this solution more adaptive to different network conditions as well as different user requirements. In addition, the multiple layers concept also makes this solution more robust to the error-prone environment, notably by applying unequal error protection mechanism to this standard [4]. Finally, the high correlation of compressed video between layers can be employed to conceal the loss of frame or block happening in the practical video transmission.

A large number of works have been introduced to conceal the frame/block loss in the previous SVC standard. For example, Chen Ying *et al.* has presented four error concealment algorithms for SVC standard including Frame copy, Temporal direct motion vector generation, Motion upsampling, and Reconstruction base layer upsampling [5]. After, the error concealment method proposed in [6] is used for the case of block lost in enhancement layer. For the case of the whole frame lost, in [7], Chen Zao *et al.* proposed an algorithm to use of the correlations between consecutive frames to estimate the lost frame.

However, to the best of our knowledge, there is very limited study on error concealment for SHVC standard. In a recent work, Ryu *et al.* has proposed an encoder – driven EC mode signaling method for SHVC [8]. In this work, the best EC mode was selected among several EC candidates from the encoder using original data. The selected EC mode is then signalized and sent to the decoder to help better concealing the lost frame. However, since this solution highly depends on the encoder original information, it is still sensitive to the error problem during the transmission, especially when the loss packet happens with the EC mode selection bits. In addition, this solution will naturally increase the computational complexity at the encoder side.

Considering the need for a powerful video transmission over error-prone environment using SHVC standard, we propose in this paper three EC solutions which mainly exploit the available information from the previously decoded layers. In the first proposal, the texture information is employed while in the second proposal, the motion information is derived for concealing the loss of frame or block. Finally, we propose a hybrid EC approach to adaptively combine the texture and motion information from the mentioned solutions to achieve a better concealed frame quality. Experiments conducted for a rich set of test conditions have shown the advancement of the proposed EC solution, notably with around 10 dB concealed frame quality improvement when compared to the conventional frame copying (FC) approach.

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The rest of this paper is organized as follows. Section II introduces the proposed error concealment algorithms while Section III presents and discusses the experiment results. Finally, section IV gives some conclusion and future works.

II. Proposed SHVC Error Concealment Solutions

A. BL contrained error concealment solutions

To the best of our knowledge, there were not many efforts on studying the whole frame loss concealment for SHVC standard. The SHVC reference software, namely SHM, is only capable of detecting frame loss and conceals this frame by simply copying the texture information from its closet reference frame in the same layer. This frame copy (FC) solution, however, is only suitable for a single layer compression scenario. In case of SHVC with multiple layers, the available information from the lower layers, i.e., base layer should be employed. Hence, our EC proposals, base layer constrained texture copying (BLTC) and base layer constrained motion vector derivation (BLMVD) are integrated into the SHVC decoder side, to exploit the available information from base layer, i.e., texture and motion vector as shown in Fig. 1.

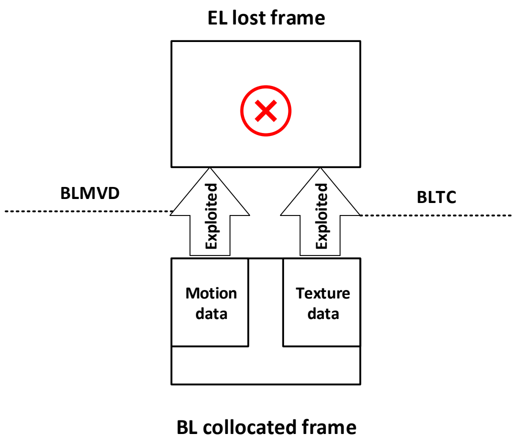


Figure 1. Conceptual diagram of the proposed EC solutions

For both solutions, the quad-tree structure and high-level syntax elements adopted in SHVC standard are adaptively used to further improve the concealed frame quality.

1) Motion Vector Derivation (BLMVD)

We propose BLMVD algorithm, which makes use of the BL motion information to perform motion compensation for currently corrupted EL frame. The advantage of this approach is that we can manipulate the quad-tree partitioning to inherit the optimal motion estimation achieved from the base layer with the original data. The proposed BLMVD based EC solution can be performed as the following two steps:

- *Motion Vector derivation*: First, the motion information from BL collocated block is derived for the EL current block, if spatial scalability is used, the up-sampling MV process [2] may be activated. For blocks without having motion information, i.e., Intra coded block, zero motion information is copied for the current EL block.
- *Motion compensation*: After obtaining the motion information, a motion compensation process is performed for each coding unit to create the concealed frame.

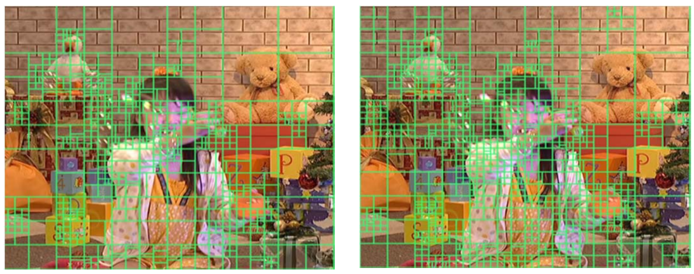
2) BL Texture Copying (BLTC)

BLTC algorithm conceals the texture of corrupted frame by simply copying the texture information from the inter – layer reference which may be up-sampled from the BL collocated frame. In this solution, the up-sampling texture information may be required if the spatial scalability is used. In this case, a 8-tap filter for Luma and 4-tap filter for Chroma may be employed [2]. The quad-tree structure from the BL is also maintained for EL.

B. Hybrid EC approach

Since the BLTC solution mainly relies on the texture information copied from the base layer, the correlation degree between the enhancement and base layers will naturally determine the quality of the concealed frame. Meanwhile, the BLMVD solution not only depends on the correlation between layers but also depends on the correlation between consecutive frames in enhancement layer. Therefore, it is able to combine the BLTC and BLMVD in a hybrid structure to maintain the strengths of each solution while mitigate the weaknesses.

The quad-tree structure adopted in HEVC and SHVC standards is a flexible block partition solution which works well for both texture and smooth areas in a picture. Hence, a significant compression improvement can be achieved with the proposed quad-tree structure [3]. Figure 2 demonstrates the optimal partition structure in video frame compression with SHVC.



BL frame El frame

Figure 2. Optimal quad-tree structure of frame number 4, PartyScene

As shown in Fig.2, for both EL and BL frames, larger blocks tend to be assigned to the background and low-motion areas while smaller blocks are for high-detailed, edged areas. It is also seen that the high correlation between the optimal quad-tree structure in the BL and EL. Therefore, it is proposed to re-use the quad-tree partition structure created from the BL for the EL.

In addition, to find a proper way of selecting the best EC solution between BLTC and BLMVD, we investigate the correlation between the SKIP mode selection information of the BL and the possibility of choosing the EC mode at the EL.

Let $P(\text{BLMVD}|SKIP\_BL)$ be the conditional probability so that BLMVD is the best solution (selected using the original data) given that BL co-located CU optimal mode is SKIP. The validation was then calculated for two testing samples extracted from *BasketballDrill* and *PartyScene* sequences as shown in Table 1.

Table 1. Validation of Skip flag

Sequence	$P(BLMVD \vert SKIP\_BL)$ (%)
BasketballDrill	86
PartyScene	88

As it can be seen from Table 1, the SKIP mode selection from the BL has a high correlation with the selection of the BLMVD at the EL, notably with around 87% of correlation. Therefore, it is reasonable to select the BLMVD solution for block having its collocated BL mode selection is the SKIP. Otherwise, the BLTC will be selected for block having its collocated BL mode selection is non-SKIP.

The proposed hybrid EC approach can be summarized as in Equation (1).

$$EC\ mode = \begin{cases} BLMVD\ if \text{ BL colocated CU is SKIP} \\ BLTC, \text{otherwise} \end{cases} \quad (1)$$

III. PERFORMANCE EVALUATION

This Section presents the performance comparison of different EC solutions, including the conventional Frame Copying, the BLTC, BLMVC and the hybrid approaches. It is started with the test conditions and followed up by the concealed frame quality assessments.

A. Test conditions

Regarding to the experiments, the whole frame loss of EL is examined. The frame loss progress is simulated with the packet loss ratio (PLR) of 10%. Test sequences are comprised of four sequences in class C [9]. For each test sequence, one I-frame is inserted for every 32 frames as so-called intra period [3]. The delta quantization parameter between EL and BL is six as suggested by the standard JCT-VC test conditions [10]. The recent SHVC reference software, SHM version 12.1 [11] is examined. The detail of the test conditions is summarized in Table 2.

Table 2. Summary of test conditions

Sequences (name, resolution, frame rate)	1. BasketballDrill_832x480@50Hz 2. BQMall_832x480@60Hz 3. PartyScene_832x480@50Hz 4. RaceHorses_832x480@30Hz
Coding structures	Random Access (GOP=8)
Quantization Parameters	EL/BL = 30/24
Total frames	300
Packet loss ratio	10%
Reference software	SHM 12.1 [11]

B. Concealed frame auality assessment

The quality of concealed frame is the main criterion to assess the effectiveness of each EC proposal. In this paper, the quality of concealed frame corresponding to each EC proposal and benchmark is measured through the pick signal to noise ratio (PSNR) [dB]. Figure 3 shows the quality variation of concealed frames with different proposed EC solutions and the No-loss benchmark while Table 3 illustrates the average quality of only frames, which are influenced by the error propagation problem.

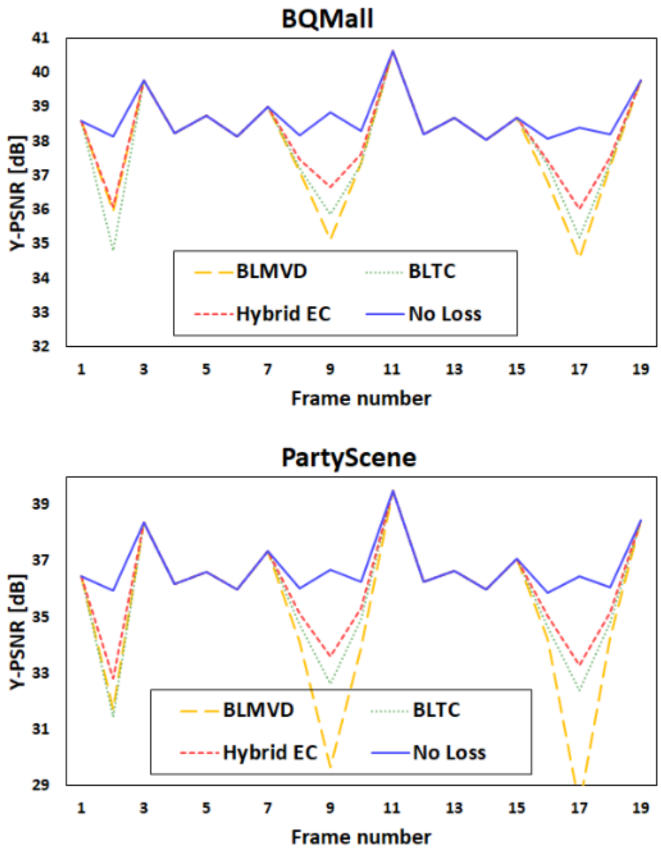


Figure 3. Quality variation for frame by frame

Table 3. Average quality of propagated frames for different EC solutions

Sequence	FC	BLMVD	BLTC	Hybrid EC
BasketballDrill	26.60	32.82	35.56	**36.45**
PartyScene	25.22	30.27	32.40	**33.46**
BQMall	23.11	34.87	35.86	**36.91**
RaceHorses	23.66	30.32	34.13	**34.45**
Average	***24.65***	***32.07***	***34.49***	***35.32***

From the results obtained in Fig. 3 and Table 3, some conclusions can be derived as:

- All three proposed EC solutions, which take into account the BL decoded information to conceal loss frames, outperform the conventional frame copying solution. This mainly comes from the fact that, the FC solution is indeed a sub-case of the BLMVD solution, notably when the BL motion information is zeros and only one of the two references is available. Hence, the quality of the BLMVD concealed picture must superior than the quality of the FC concealed picture.

- For test sequences with fast motion characteristics like *RaceHorses* or *BasketballDrill,* the BLTC solution significantly outperforms the BLMVD solution. In this case, the BLMVD solution is typically unsuitable for concealing the loss frame since it mainly relies on the temporal correlation between frames. Thus, the BLTC should be a best choice for such sequences.

- Performance assessment shown in Fig. 3 again emphasizes that the Hybrid EC approach is superior to other proposed EC solutions, i.e., the BLTC and BLMVD. This reflects the accuracy of our assumption about the correlation between the SKIP mode selection at the BL and the selection of the BLMVD solution at the EL.

IV. CONCLUSIONS

In this paper, we present three EC solutions for video transmission over error prone environment using SHVC standard. The proposed EC solutions mainly rely on the BL decoded information, i.e., the BL texture and BL motion vector information. In addition, we present a hybrid EC approach to adaptively combine the concealed information created from each EC candidates. The proposed EC hybrid strategy is based on the high correlation between the SKIP mode selection at the BL and the BLMVD selection at the EL concealment scheme. Experimental results shown that the all three EC proposals significantly outperform the conventional frame copying based EC approach. The future works will consider optimizing the hybrid strategy and take into account the EL temporal and spatial correlations for creating a better concealed frame.

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