

Error Concealment for SNR Scalable Video Coding

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Abstract

This paper proposes an efficient error concealment method for SNR scalable coded video. The algorithm adaptively selects a proper concealment candidate from the base or the enhanced pictures to conceal the artifact of a lost enhancement block. To determine the best concealment candidate, we propose a trial process in which the concealment candidates are examined based on two criteria: 1) picture continuity at the border of concealed macroblocks, and 2) to satisfy the coding distortion bound of the base layer coefficients when they are available. For the latter, requantization of the concealed picture with the base layer quantizer step size and its dequantized pixels should result in zero distortion. We have implemented the method on a proposed SNR scalable H.264 video codec and compared the decoded video quality against just copying the base layer pixels into the enhanced picture. Simulation results show that the proposed method can achieve a considerable improvement by up to 3dB especially in situations where the enhancement layer contains a large portion of the picture information. This will make scalable video transmission more successful over unreliable channels.

Key words: Error/Loss concealment, SNR scalability.

1 Introduction

In video transmission over a variety of communication channels, receiving all video data is not guaranteed and parts of these data may be lost or some bits may be received in error. To address this problem several efforts have been considered to make video bitstreams robust to channel errors. Scalable coding is one of the successful methods of delivering video contents over heterogeneous channels and provides a robust error protection tool [1–3].

A scalable video coder provides a base layer that contains a decodable video with low quality and one or more enhancement layers that contain additional

data necessary to improve video quality. It has been shown that if the base layer is better protected than the enhancement layers, a more successful video transmission will be achieved [3–5]. However, there is still a significant probability that video contents are lost, hence effective error concealment methods should be applied in the decoder to visually minimize the impairments of the lost parts of each picture. In non-scalable codecs, in an intraframe, the correctly received neighboring macroblocks (MBs) are used to conceal a lost MB, and in an interframe, typically the MBs of the previous frames are used [6–9].

In a scalable codec when an enhancement MB is missed, the concealment candidates can be among the blocks from the previous enhanced frame or the current frame of the base layer. The straightforward method is to replace the enhanced block with the corresponding base layer reconstructed block. We call this *upward* method. Since the base layer is often more protected and so is more reliable than the enhancement layer, selecting the concealment pixels from the enhanced pictures might even increase the distortion. However, if the enhanced reference frame is received correctly it can generate a better concealment block. In [10] the loss concealment is carried out from the previous enhanced picture only if it is received correctly, otherwise, the current reconstructed picture is used. In [11] and [12] by assuming that the base layer data are error free, the enhanced concealment block is calculated from the base and the enhanced pixels. The concealment method of [13] also uses the texture data of both layers, but does not efficiently exploit the available motion vectors.

In this paper we propose a more efficient error concealment method for the enhancement layer. Firstly, if the enhancement layer MB is correctly received but in the absence of the base data, instead of ignoring the enhancement data, we use them as efficiently as possible. Secondly, to conceal a lost MB in the enhancement layer, the available data of both base and enhancement layers are examined and the best one is selected. We propose an efficient trial process in which the loss concealment candidates among the base and enhancement motion compensated pixel blocks are examined based on two criteria: 1) picture continuity around the concealed block borders, and 2) compatibility of coefficients with the base layer. Simulation results show that this method of error concealment has a significant improvement over the conventional concealment methods. The proposed method has the advantage that it considers the possible losses in the base layer as well as the enhancement layer and also adaptively uses all the available data for concealment in all circumstances.

The remainder of this paper is organized as follows. Section 2 describes the employed base layer error concealment which is the basis of our enhancement error concealment. Section 3 describes how the correctly received enhancement data are used in the absence of the lost base data as well as classifying the different error situations and their corresponding loss concealment candidates. In section 4 the proposed error concealment trial process to select the

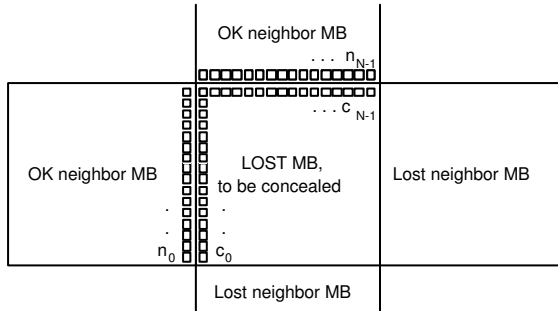


Fig. 1. Edge discontinuity, the center MB is lost and left and upper neighbors are correctly received.

best candidate is described. Finally, section 5 provides the simulation results followed by a conclusion in section 6.

2 Error concealment in the base layer

As mentioned earlier, the base layer of an SNR scalable coded video is exactly a standard non-scalable bitstream. Therefore, for its error concealment we employed the proposed algorithm of [9], in which the motion compensated blocks with all the surrounding motion vectors (MVs) of a lost MB are examined. The neighboring MV that results in a minimum edge discontinuity [14] would be selected as the recovered MV and its motion compensated block is chosen as an estimate of the lost MB. As Fig. 1 shows the edge discontinuity can be calculated from the difference between the edge pixels of a loss concealment candidate (c_i) and the correctly received (or repaired) neighboring blocks (n_i):

$$D_e = \frac{1}{N} \sum_{i=0}^{N-1} |c_i - n_i|, \quad (1)$$

where N is the edge length equal to $16 \times k$ pixels with k equal to 1 to 4, being the number of correctly received adjacent MBs. If all the surrounding MBs of a missed MB are lost, recovering the correct MV is not carried out and the loss concealment would be simply copying the pixels on the same position from the reference picture. It should be mentioned that the concealing pixels are just the elements of the motion compensated block without adding any residual data, since no such data are received.

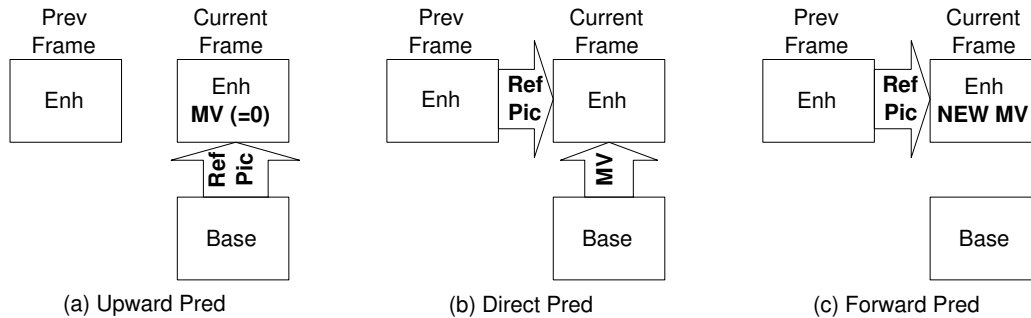


Fig. 2. Reference picture and motion vectors in the three enhancement prediction modes of SNR scalability of [4].

3 Enhancement error concealment

3.1 The prediction modes in the employed SNR scalable codec

To design an error concealment in the decoder, the characteristics of the encoder regarding the dependencies between the base and the enhancement layers should be considered. In the employed SNR scalable method [4,5], in encoding of every block in the enhancement layer, the motion compensation is made in one of the upward, direct or forward prediction modes. In the upward mode shown in Fig. 2(a), the reference picture is the base layer reconstructed picture and the MVs are equal to zero. In the direct mode of Fig. 2(b), motion compensated previous enhanced picture (or pictures) with the motion vector of the base layer is used. Finally, in the forward mode of Fig. 2(c), motion compensated previous enhanced picture uses its own new set of enhancement motion vectors. After selecting the mode at the encoder and performing motion compensation, the difference between the source and the predicted block is transformed, quantized and entropy coded. The quantization step size of the enhancement layer (QE) is smaller than that of the base layer (QB), so the enhanced pixels will improve the quality. For more details of the used SNR scalable codec the reader is referred to [4,5].

3.2 Concealment strategy in different situations

In an SNR scalable codec the data of every macroblock are divided into two or more layers which are accommodated into different packets [4]. Therefore, in the case of error, it is possible that one layer is correctly received and the other one is lost. Various possible situations are listed in Table 1, in each case we have a different loss concealment strategy as follows.

If the enhancement layer is lost, the enhancement prediction mode of the en-

Table 1
 Macroblock enhancement concealment candidates in different situations.

Situation	Orig Enh Pred Mode	Concealment Candidates
Base Lost/OK, Enh Lost	Unknown	Upward, Direct
Base Lost, Enh OK	$\left\{ \begin{array}{l} \text{Upward/Direct} \\ \text{Forward} \end{array} \right.$	Upward, Direct, Decoded
		Decoded

coder is unknown. Therefore, regardless of whether the base layer is lost or not we have two different candidates: Upward, and Direct. Note that these candidates are identical to the motion compensated prediction blocks described in Section 3.1 without adding any residual data. We do not attempt any forward mode since it will cause misleading choices. The reason is that in typical scalable video transmissions, the enhancement layer data are less reliable than the base layer, and are highly probable to be received in error.

The next situation is when an MB in the base layer is missed, but the enhancement MB data are correctly received. In this situation, the enhancement data are almost useless and all the standard decoders ignore them. In the employed codec, when the MB is encoded in the direct or upward mode, the data (MV for direct, and reconstructed pixels for upward) of the corresponding base layer MB have been directly used to code the enhancement layer. Therefore, since the base data are lost the enhancement data are almost useless and the block is considered as corrupted. However, these blocks are still decoded and reconstructed using the repaired base layer data. This reconstructed macroblock will subsequently go to a trial process and will be selected if it has the lowest discontinuity. Note that this concealment candidate, named as 'Decoded' in table 1, is the motion compensated block containing the decoded residual data.

If the encoded enhancement block is in the forward mode, the data of the base layer have not been used for prediction and coding. However, for arithmetic coding of the enhancement MVs, the base MVs have been used to code them more efficiently [4]. This method has had a compression gain of around 1-2 per cent in coding the enhancement MVs. If we give up this gain in the encoder and code the enhancement layer MVs completely independent of the base layer data, the enhancement MB in forward mode can be predicted and decoded regardless of whether the data from the base layer are received or not. In this case we do not attempt any other error concealment trial. Our simulations show that if we decode these forward MBs, the final quality has up to 0.5 dB improvement if the base and the enhancement layers experience the same bit error rates (BER). When the base layer is error free or due to unequal error protection it has a very low BER, obviously there would not be any of these

MBs and hence such improvement is not expected.

4 Trial process for the concealment of a corrupted enhancement MB

We consider up to three loss concealment candidates for a corrupted MB in the enhancement layer; upward concealment, direct concealment and decoded data as listed in table 1. The most important part of the error concealment would be to select the best choice among these candidates. If the decoder was able to calculate distortions of the above three candidates with regard to the source pictures and so selected the best one that has the minimum distortion, a considerable improvement in error concealment would have been achieved. We apply this and use it in our assessment as the upper bound for quality improvement. However, this ideal selection is not possible and in practice we can estimate the loss concealment discontinuity (D) which consists of two components; D_b and D_e . D_b corresponds to the candidate's compliance with the base layer coefficients and D_e is associated with the enhancement layer boundary discontinuity.

To generate D_e , if any neighboring block in the enhancement layer is correctly received, the absolute difference between the edge pixels of those blocks and the concealment candidate is calculated and normalized as shown in equation (1). Fig. 1 shows an example where two out of four neighboring blocks are correctly received. Note that if there is no correctly received MB, no D_e needs to be calculated.

The other discontinuity criterion, D_b , is calculated using the corresponding base layer data based on the fact that in SNR scalability in the upward prediction mode, the amplitude of the residual DCT coefficients of the base layer which comprise the enhancement layer data are smaller than the base layer quantization step size (QB). In other words, what is actually coded in the enhancement layer as the residual data, is the quantization distortion of the base layer [1]. In the forward and direct prediction modes also these coefficients are almost in the range of -QP to +QP. That is why they should be quantized with step sizes (QE) smaller than QB, otherwise if they were requantized with QB, the results would be zero and no quality improvement would have been achieved by the enhancement layer. Thus, if the difference between the concealment macroblock candidate and the base MB is transformed, quantized with the corresponding QB and subsequently reconstructed as shown in Fig. 3, all coefficients of the resulting block should be zero. However, for incorrect candidates these coefficients (R_i) may have nonzero values, the normalized sum of which is calculated by:

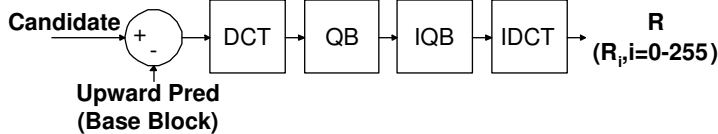


Fig. 3. The process of calculating the base related discontinuity.

$$D_b = \frac{1}{256} \sum_{i=0}^{255} |R_i|. \quad (2)$$

If the selected lost concealment block is the correct one, according to the above discussion D_b should be close to zero. It is obvious that if the loss concealment choice is upward, this criterion would always be zero. However, for the direct candidate it may have another value. It should be mentioned that if the base MB is corrupted or lost, D_b would not be calculated.

Finally, the overall discontinuity measure is calculated as follows:

$$D = \begin{cases} (D_b + D_e)/2 & \text{if both } D_b \text{ and } D_e \text{ exist,} \\ D_b \text{ or } D_e & \text{if one of them exists,} \\ None & \text{if none of them exists.} \end{cases} \quad (3)$$

The loss concealment candidate that has the lowest discontinuity is selected as the best choice, and if D is not calculated such as the case *None* in eq. 3, only the upward candidate would be chosen.

5 Simulation results

We have incorporated the proposed loss concealment method into our H.264 SNR scalable decoder [4]. At the encoder side a choice was made to code the enhancement MVs independent of the base MVs. The Foreman and News video sequences were selected and coded when the independent MV coding switch was disabled or enabled. When it was disabled the bitstreams were decoded and the losses were concealed only with the upward concealment, and in the other mode, bitstreams were decoded with the new loss concealment method. We also examined two different settings for the base and enhancement quantization parameters: QPB and QPE respectively. At the first setting (QPB=45 QPE=25) there is a large difference between the base and enhancement layer quality, and the second one (QPB=35 QPE=25) has a lower difference in quality. All the coded videos have one error-free intra frame at the beginning followed by 33 interframes, each in two layers. The frames are divided into 9 slices to have a good error resilience.

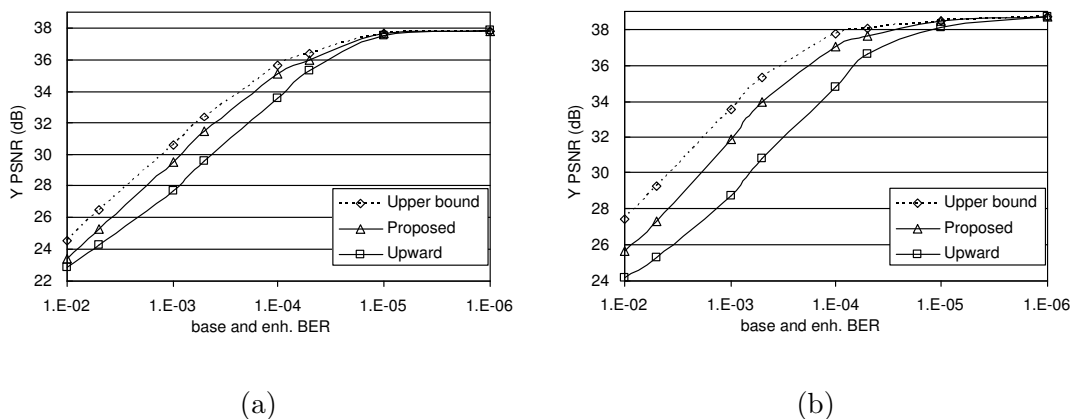


Fig. 4. EEP, QPB:45 QPE:25, (a) Foreman (base 18, enh 105 kbps), (b) News (base 15, enh 72 kbps), QCIF@10Hz.

Figs. 4 and 5 show the average of 100 simulation runs of the tests when the base and the enhancement layers are both equally error protected (EEP) and have the same bit error rates (BER). The upper bound curves show the maximum possible gains when the algorithm has access to the source pictures for its best candidate selection. From the diagrams it can be seen that the proposed method has improved the quality by up to 3dB compared with the conventional upward loss concealment method. This gain is more significant for a larger difference between the quality of the layers (i.e. QPB=45 QPE=25). This is because in this situation due to its larger information content, the enhancement layer can improve the quality of the concealed MB more effectively. It should be mentioned that at high error rates (e.g. $10e-2$), since a significant number of neighboring MBs are corrupted, the error concealment method has less impact. On the other extreme, at low error rates the majority of MBs are error free and obviously no error concealment needs to be applied.

Our subjective observations also show a noticeable improvement on the quality of loss concealed pictures. Fig. 6 shows a snapshot of the News video sequence coded with QPB=45 and QPE=25, at BER= $10e-3$. The error pattern is the same for both tests, but it is clear that the one concealed with the proposed algorithm has a better quality than the other one. For example, the head of the dancer in the background is totally distorted in the upward method because of a propagated error in the base layer, while our proposed method has recovered the lost blocks more effectively only from the enhancement information. Moreover, there are more recovered picture details in Fig. 6(b) than Fig. 6(a) since the upward method only uses the low quality data of the base layer.

To evaluate the algorithm in unequal error protected (UEP) scenarios, we repeated the experiments by assuming that the base layer is always error free and only the enhancement layer is erroneous, as shown in Figs. 7 and 8. In

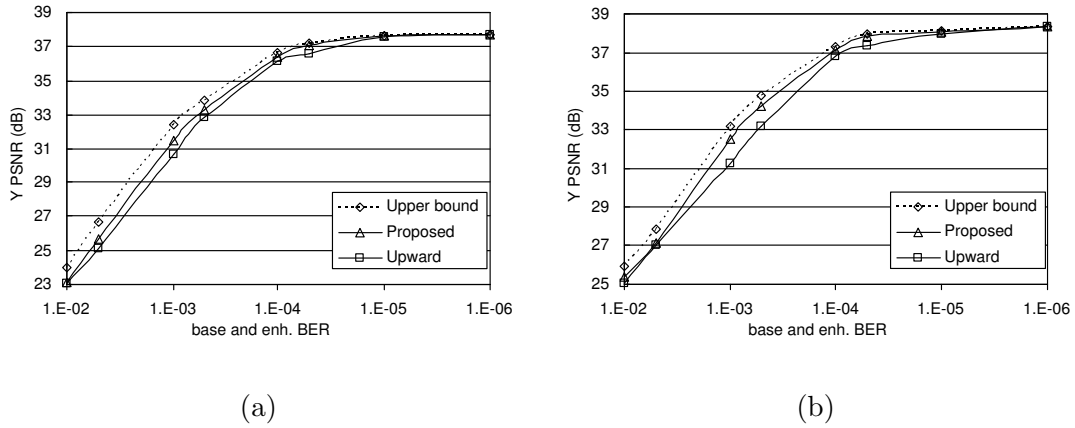


Fig. 5. EEP, QPB:35 QPE:25, (a) Foreman (base 33, enh 98 kbps), (b) News (base 29, enh 62 kbps), QCIF@10Hz.



Fig. 6. Frame 33 (100 in original) News QPB:45 QPE:25, EEP, BER = 10e-3, (a) Upward, (b) Proposed.

this situation the loss concealment discontinuity measurement is more effective since all the base layer MBs are correctly received. As might be expected, there is no improvement from the independent MV coding. Nevertheless, the proposed method still has a clear improvement over the upward method. For assessment of visual quality, Fig. 9 shows a snapshot of loss concealment for the same frame of Fig. 6, but in this case, the base layer is safely received. Since the conventional upward method does not exploit the enhancement layer concealment and only relies on the base layer contents which are coarsely quantized, the difference in quality between Fig. 9(a) and our method in Fig. 9(b) is evident.

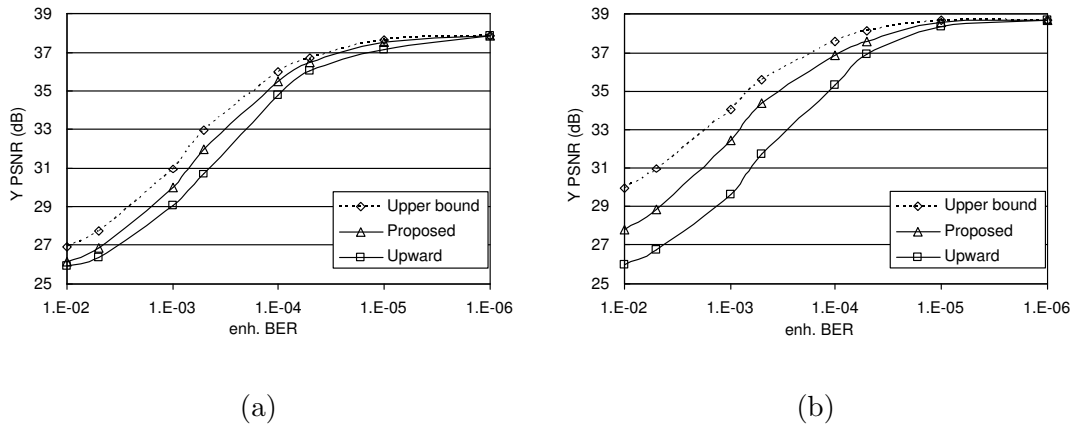


Fig. 7. UEP, QPB:45 QPE:25, (a) Foreman, (b) News.

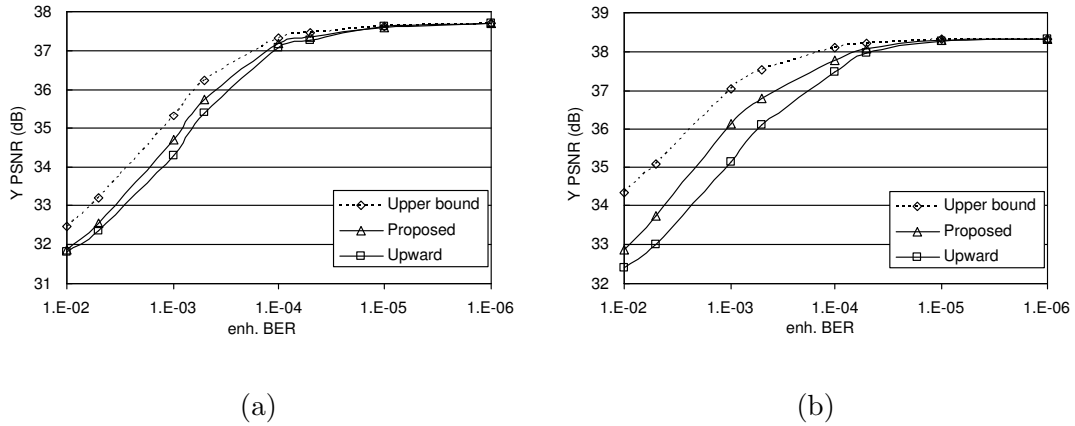


Fig. 8. UEP, QPB:35 QPE:25, (a) Foreman, (b) News.

6 Conclusion

An error concealment method for SNR scalable video coding has been presented. It uses the data of both base and enhancement layers to conceal the corrupted parts of the pictures. To optimally select the best candidate between the base and the enhancement layer predictions, the correctly received data of both layers are used in the measurements. The simulation results show a significant improvement in both scenarios when the base and enhancement layers are equally protected and the case when the base layer is error free. Furthermore, it is shown that when the quality difference between the base and enhancement layer is large, the proposed algorithm is more efficient.



Fig. 9. Frame 33 News QPB:45 QPE:25, UEP, BER = $10e-3$, (a) Upward, (b) Proposed.

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