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A HYBRID ERROR CONCEALMENT FOR INTRA FRAME IN STEREOSCOPIC VIDEO

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ABSTRACT

A hybrid error concealment method is proposed for slice losses in intra frames of view plus depth stereoscopic video. GOPs are offset between the view and depth sequences to guarantee the frame in the other sequence corresponding to the intra-frame is not intra mode. For lost regions near the edges in the frame, the MV is recovered from the corresponding depth frame. For other regions where the corresponding MVs in the depth frame are not available, the MV is recovered from co-located MB and its neighboring MBs in previous frame. If the boundary match distortion of these MV candidates is higher than a threshold, motion estimation (ME) will be re-executed for the neighboring MBs of the lost region. Experimental results show that the proposed method is more effective than existing methods.

Index Terms— Error concealment, view plus depth stereoscopic video, intra frame

1. INTRODUCTION

One solution for 3D video is view plus depth format because it can be stored and transmitted efficiently [1] [2]. We can find many 3D error concealment schemes utilizing the correlation between two view sequences [3] [4] [5] or view plus depth sequences [6] [7]. In [6] and [7], the motion correlation of depth and view is exploited so that the view motion information is used for prediction during depth map coding and then used to conceal transmission errors at the decoder. This performs better than applying error concealment for 2D view and depth map video separately. But it is not often feasible for the recovery of lost slices in view sequence because the depth map does not contain any texture information. Moreover, it cannot distinguish different objects at the same distance with the camera, even if they have relative motion [8]. In [8], the authors jointly consider the neighbor motion information and the corresponding depth to recover the lost MVs for the corrupted blocks.

None of the methods above consider the error concealment problem for the intra frames, because the corresponding frames in the depth sequence are also intra mode where there is no MV available. Conventional error concealment methods for intra frames are spatial interpolation [9] [10] or zero copy from the co-located region in previous frame for simplicity. The results are often poor. Another effective solution for this problem is to implement motion estimation at the decoder [11]. However it increases the computational complexity considerably.

In this paper, we proposed a hybrid error concealment method, that is the depth-offset method and decoder motion re-estimation method are combined efficiently for the slice losses of intra frames in the view sequence of 3D. The motion correlation of view and depth sequences is exploited to achieve higher recovered intra frame quality while lower the computational overhead. The algorithm then adaptively acquires motion vectors of neighboring MBs from the previous inter frame or uses motion re-estimation according to object-based boundary match distortion which can further improve the error concealment quality, especially for the regions with rich texture in the view sequence.

The rest of this paper is organized as follows. Section 2 elaborates on the proposed intra frame error concealment method. The experimental results are shown in Section 3. We conclude this paper in Section 4.

2. HYBRID I-FRAME ERROR CONCEALMENT

2.1 Depth-Offset Error Concealment

In order to extract MV candidates from the depth sequence, the frame that corresponds to the frame with slice losses in the view sequence should not be intra mode. We made the depth sequence one frame offset from the view sequence by repeating the first frame in depth one time which is shown in figure 2.1(a). The disadvantages of this solution are the 1-frame delay of the depth sequence and extra bits for the added frame. Another solution for this problem is to let the length of the first GOP differ from others in the depth sequence. As shown in Fig 2.1(b), we let the length of the first GOP (G_{L0}) be unequal to the others which have length

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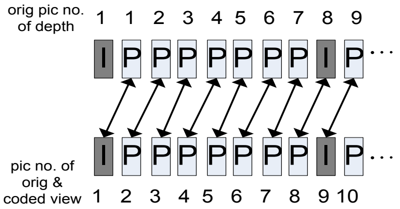
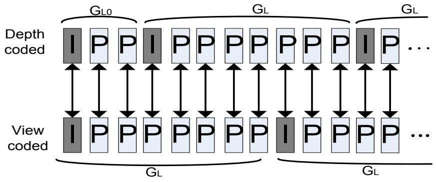
G_L. For simplicity, we only use the first solution in our simulation.



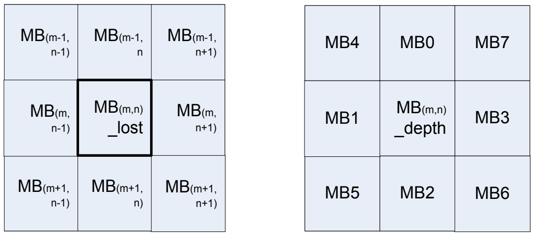
(a) Repetition of 1st frame



(b) different length of 1st GOP

Fig. 2.1 Alignment of view and depth sequence

For the lost slices in the view frame, the MVs of the co-located MB and its neighboring four ($MB_{0\text{-}3}$) or eight ($MB_{0\text{-}7}$) MBs in the corresponding depth frame can be used as the MV candidates as shown in Fig.2.2. Then the boundary match algorithm [12] (BMA) is used to choose the optimal one. We use object-based BMA for a higher accuracy to find the optimal MV and compare the distortion value with a fixed threshold. Fig 2.3 illustrates the object-based BMA. The depth map shows a foreground object and background. In the view sequence, the side match distortion for a candidate concealment block is only computed for the sides which don't cross an object boundary. We refer to this method as depth-offset error concealment.



(a) I-frame in view (b) corresponding P-frame in depth

Fig. 2.2 Corresponding MBs between view frame and depth frame

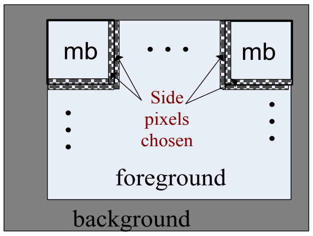
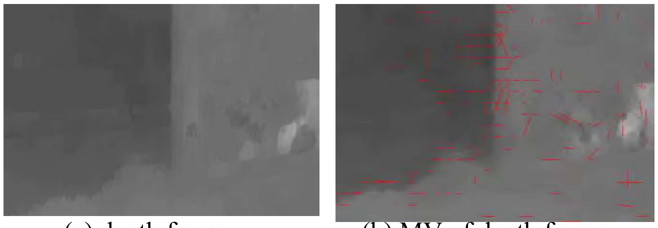


Fig. 2.3 Illustration of object-based BMA

As we know, a whole object in the depth map is homogeneous even if it has various types of texture in the corresponding view sequence. Fig. 2.4 and Fig. 2.5 show an example. The big moving wall in this picture contains some letters on it (Fig. 2.4(a)). But all these letters cannot be seen in the depth (Fig. 2.5(a)) because they have the same depth as the wall object. The motion vectors shown in Fig. 2.5(b) of these regions detected from the depth sequence are almost zero, except for the region near the edge of the wall. So the recovered result of the letters within the wall may be bad as the arrows indicate in Fig. 2.5(b) if we only use the MVs from the depth sequence.

(a) (b)

Fig. 2.4 Illustration of slice loss of an I frame in view seq. and error concealment result using the depth-offset method



(a) depth frame (b) MV of depth frame

Fig. 2.5 Illustration of homogeneous moving object within the depth sequence

2.2 Proposed Hybrid I-Frame Error Concealment

In the case above, we need additional MV candidates. We estimate the MVs for the neighboring MBs of the lost one in the view sequence. These estimates can be acquired either from the previous inter frame or by motion re-estimation at the decoder. For lowering computational overhead, we set a fixed threshold for the boundary match distortion value of the recovered MB using above method. The threshold is set according to the average luminance value of the current recovered MB (ave_{MB}) as shown in equation (1) for the reason that human eye is less sensitive to lighter or darker area than gray area. Only when the distortion value is higher than the threshold or the co-located MB and its neighboring ones in the previous P frame in the same sequence are lost, the motion estimation is implemented. Otherwise the MVs from the co-located MB and its neighboring ones in the previous P frame are used as MV candidates directly. Then BMA is used again to decide the optimal result.

$$\mathrm{Th} = \begin{cases} 20 & if 0 \leq ave_{MB} \leq 63 \ or \ 192 \leq ave_{MB} \leq 255 \\ 5 & if \ 64 \leq ave_{MB} \leq 191 \end{cases} \quad (1)$$

The procedure of the proposed hybrid error concealment method for I frame slices in the view sequence presented in Fig. 2.6 is as follows.

First, if the corresponding MB in the depth stream is also lost, the lost MB in the view sequence is only recovered by 2D intra frame linear interpolation error concealment. Otherwise the depth-offset method (part (I) in Fig. 2.6) is run, and its results evaluated. If the object-based boundary match distortion (OBBMD) is higher than the threshold, we expand the set of candidate MVs by considering the MVs of the co-located MB and its four neighboring ones in the previous neighboring P frame in the view sequence (part (II) in Fig. 2.6). If they have been lost or the distortion value is still higher than threshold, then motion re-estimation is adopted to further expand the set of candidate MVs by computing MVs of the neighboring MBs of the lost MB. BMA is again used to get the best choice (part (III) in Fig. 2.6) .

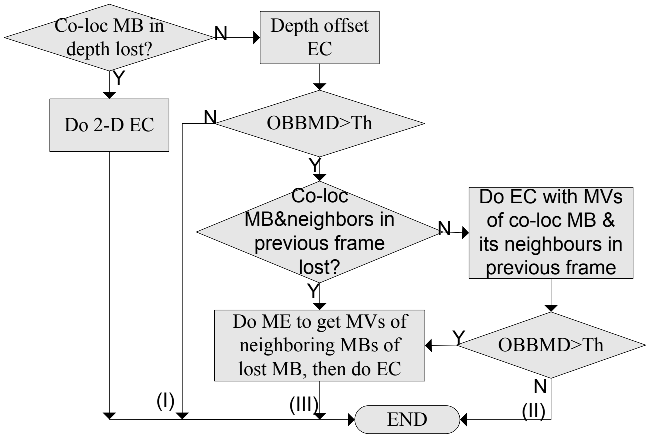


Fig. 2.6 Flow diagram of the proposed hybrid error concealment procedure

3. SIMULATION RESULTS

We implement our algorithm based on H.264 reference software (JM12). The view and depth sequences of 3 test sequences are in 4:2:0 format. We take the average Y-PSNR of I-frames and of all frames of the whole GOP. The parameters of three sequences are set as following: Wall (640x320), Mobile (640x512) and Tank (384x256) sequences are encoded with the GOP length of 8 and an I-P-P-P format. Length of each sequence is 50 frames. The quantization parameters are set as 18 for the video stream and 28 for the depth stream. Motion estimation is carried out at 1/4-pixel resolution with a search range of 32 pixels. A slice is encapsulated in a packet with a fixed number of 25, 40 and 12 MBs for the three sequences. Slices are dropped randomly in the I-frame of the view sequence. 5%, 10% and 20% packet loss rates (PLR) are tested separately.

We compare the proposed error concealment method with the linear interpolation method (L_interp) implemented in JM12, co-located copy from previous frame (Co-loc), motion re-estimation at the decoder (ME_based) and depth-offset error concealment (D-offset) method.

The average Y-PSNR results of view sequences using different methods with different PLR are shown in Table 3.1-3.3. From these comparisons, it can be seen that our proposed algorithm improves objective quality considerably.

Table 3.1 Ave_PSNR(Y) with 5% slice loss rate

EC method	Wall		Mobile		Tank	
	I	GOP	I	GOP	I	GOP
L_interp	35.00	35.21	36.19	36.31	34.53	34.93
Co-loc	32.43	33.48	36.05	35.27	32.45	33.87
ME_based	40.79	40.18	43.70	42.92	39.66	40.27
D-offset	33.77	34.34	43.58	42.97	35.94	37.30
Proposed	45.14	44.98	43.74	42.85	41.30	41.39

Table 3.2 Ave_PSNR(Y) with 10% slice loss rate

EC method	Wall		Mobile		Tank	
	I	GOP	I	GOP	I	GOP
L_interp	30.51	30.83	33.14	33.28	30.36	31.73
Co-loc	29.07	29.16	32.82	31.75	30.51	30.68
ME_based	35.81	34.73	41.19	40.30	37.62	37.33
D-offset	31.05	31.11	40.51	39.64	34.40	34.12
Proposed	37.78	37.32	41.36	40.35	39.00	39.06

Table 3.3 Ave_PSNR(Y) with 20% slice loss rate

EC method	Wall		Mobile		Tank	
	I	GOP	I	GOP	I	GOP
L_interp	26.39	26.58	29.15	29.55	29.14	29.50
Co-loc	27.40	26.54	28.25	27.31	29.20	29.00
ME_based	33.63	32.75	37.46	38.03	35.37	34.82
D-offset	29.25	29.60	36.19	36.69	31.92	31.33
Proposed	35.22	35.03	37.74	38.40	36.82	36.68

The time fraction of each of the three parts of the flow diagram in Fig. 2.6 is given in Table 3.4 with 20% PLR of whole stream. The motion re-estimation takes only a small part so it cannot increase computational overhead greatly.

Table 3.4 Time fraction ratio

	(I)	(II)	(III)
Wall	86.61%	13.33%	0.06%
Mobile	89.93%	9.99%	0.08%
Tank	66.64%	33.31%	0.05 %

Fig. 3.1 and 3.2 illustrate two examples of the depth-offset method and the proposed method. The subjective improvement is also significant especially in moving objects with rich texture.

4. CONCLUSION

We proposed a hybrid error concealment method for slice losses in the I frame of 3D video compressed in view plus depth format. The I frame in the view sequence is offset from its corresponding depth sequence so that it can align with a P frame in depth sequence. The MVs of collocated MB and its neighboring ones in the depth P frame are utilized for corresponding MB error concealment in view frame. If the object-based boundary match distortion of the recovered MB is higher than a fixed threshold, MVs from collocated MB and its neighboring ones in previous view frame are also utilized and then recalculate OBBMD. Finally, motion re-estimation for the neighboring MBs of the lost one is adopted if OBBMD is still higher than the threshold or the MBs in previous frame are also lost. The experimental results show that the proposed scheme can vastly improve the quality of the recovered video.

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(a) original (b) slice loss

(c) depth-offset (24.70dB) (d) proposed (31.78dB)

Fig. 3.1 11th frame of the “Wall” seq.

(a) original (b) slice loss

(c) depth-offset (32.26dB) (d) proposed (33.46dB)

Fig. 3.2 8th frame of the “Mobile” seq.