AN IMPROVED DMVE TEMPORAL ERROR CONCEALMENT

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ABSTRACT

During video transmission over error-prone networks, the compressed bit stream is often corrupted by channel errors which may cause the video quality degrading suddenly. In this paper, we present a novel temporal error concealment technique as a post-processing tool at the decoder side for recovering the lost information. In order to recover the lost motion vector, an improved Decoder Motion Vector Estimation (DMVE) criterion is introduced which considers temporal correlation and motion trajectory together. We utilize pixels in the two previous frames as well as surrounding pixels of the lost block. The best motion vector is determined according to the criterion, and then the lost pixels are recovered using motion compensation. Simulations show that the proposed technique can achieve remarkable objective (PSNR) and subjective gains in the quality of the recovered video.

Index Terms— Temporal error concealment, decoder motion vector estimation, temporal correlation， motion trajectory

1. INTRODUCTION

Most channels such as wireless channels and the Internet are not reliable enough to provide error-free transmission. The long-term and short-term fading effects in wireless channels and the packet loss and delay in the Internet are inevitable. Meanwhile, existing video compression standards such as MPEG and H.264 [1] are block-based structure. The bit stream encoded by those standards is very sensitive to transmission errors. Even the error of one single bit often leads to the whole block being un-decodable and the motion-compensation scheme will propagate the error to the latter frames. It will cause serious degradation in the visual quality of the decoded image at the receiver. Error concealment (EC) techniques are widely adopted in video applications that are implemented at the decoder to conceal the erroneous blocks using the correctly decoded information [2]. Comparing to other existing error resilient approaches, no extra delay or redundant information will be added. It can be applied without modifying the source and channel coding schemes.

EC method can be classified to two categories: Spatial Error Concealment (SEC) and Temporal Error Concealment (TEC). SEC exploits the correlations that exist between a damaged macroblock (MB) and its adjacent MBs in the same frame while TEC methods focus on using the correlations that exist in successive frames to recover the lost motion vector (MV) [3]. In fact, temporal correlation is much higher than spatial correlation in real world image sequences so that TEC can be more effectively than SEC. The key point in TEC method is to estimate the lost MV of the damaged blocks [4]. Basic TEC methods replace the missing vector of a corrupted MB with the zero MV or the average or median MV of adjacent received MBs. Improvements can be obtained when the candidate MVs are evaluated under some matching measure to choose the substituted MV. The Boundary Matching algorithm (BMA) [5] selects the optimal one that minimizes the boundary matching error. It has been adopted as the TEC method in the H.264 JM decoder [6]. The Decoder Motion-Vector Estimation (DMVE) [7] which uses small neighboring regions to process temporal matching is another representative TEC method. The DMVE algorithm leads to substantial improvement in concealment performance and is considered as more effective than the BMA [8].

In this paper, we present a new TEC algorithm which adopts an improved DMVE criterion. The new criterion considers temporal correlation and motion trajectory together and utilizes the intensity information in the previous two frames to estimate the lost MV of the erroneous blocks. Simulation results demonstrate that the proposed algorithm can conceal the erroneous blocks more effectively and remarkably increase the visual quality.

The rest of this paper is organized as follows: In Section 2, the DMVE will be reviewed first. Then the proposed improved DMVE algorithm will be described in details in Section 3. The experimental results and comparison with the conventional BMA and DMVE are shown in section 4. Finally, the conclusion is provided in section 5.

This work was done while the 1st author is an intern in Philips Research Asia – Shanghai.

2. REVIEW OF THE DMVE ALGORITHM [7]

The DMVE algorithm aims to accurately estimate the motion vector of any lost MB using correctly received information at the decoder. It is achieved by carrying out a process similar to the motion estimation process performed at the encoder in order to determine the missing MV.

When packet loss occurs, several lines (two to eight) of pixel intensity information around the lost MBs are taken. This includes available information in the MB above the lost one (even if this MB is itself a concealed MB), the MB below the lost one (if received correctly) and the MB on the left of the lost one (even if this MB is itself a concealed MB). In addition, the algorithm includes pixels from the above left (even if this MB is itself a concealed MB) and below-left MB (if received correctly) to complete the encirclement of the lost MB. If we assume that only two surrounding lines are used and that all the required MBs in the current picture are available, the pixels used are as shown in Fig. 1.

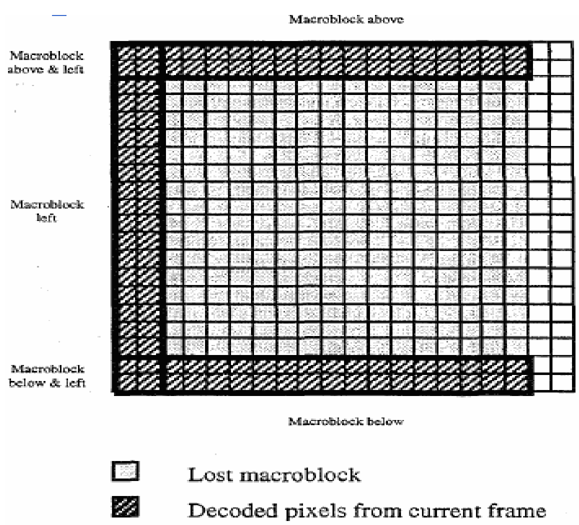


Fig. 1 matching area employed in DMVE algorithm

The algorithm then performs a full search within the previous picture in order to find the best match to the available lines of decoded pixels from the current picture defined, i.e., minimization of Sum Absolute Difference (SAD). The MB of data which is surrounded by the lines which best match the lines from the current picture is assumed to be the best match to the lost MB.

3. PROPOSED ALGORITHM

In DMVE algorithm, the MVs of available neighboring MBs are used as candidate MVs for the lost MB. This procedure utilizes the correlations of the MV's existing in spatially adjacent MB's, often the MV of a certain MB is the same or very close to the MV's of its spatially adjacent MB's [9]. Meanwhile, there is a high correlation of the MVs in temporal direction especially in low motion sequences. It is based on the fact that motion does not change much in a short time period, i.e. from frame to frame, due to inertia of moving objects. The constant motion velocity model is considerable accurate for most sequences.

Another notable characteristic of the MV is that the intensity field is homogeneous along the motion trajectory. When the constant motion velocity model is valid, the intensity information in the previous two frames can be used to find out the true motion trajectory. For a lost MB, the MB moving along the motion trajectory to its position can be a good estimation of the lost area. So we try to combine this temporal correlation property with the previous described DMVE assumption to form a new criterion, which provides a more accurate motion model for the lost area.

The proposed improved DMVE temporal error concealment includes five main steps as shown in Fig. 2:

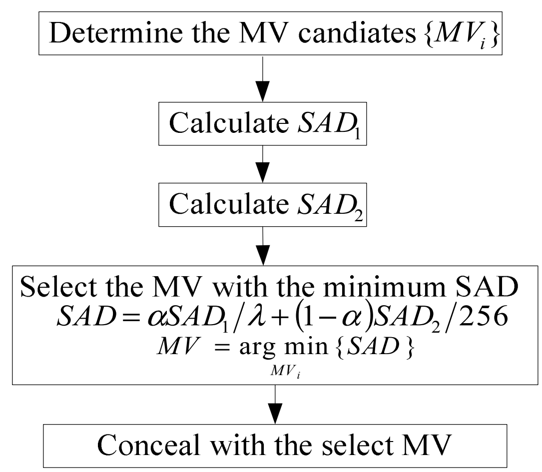


Fig.2 the flow of the proposed algorithm

Step 1: Determine the MV candidates $\{MV_i\}$: the MV for the same location in the previous picture; the MVs associated with available neighboring MBs; the median of the available neighboring MBs; the average of the available neighboring MBs; the zero MV.

Step 2: Calculate the difference as SAD_1 between the neighboring area around the missing MB within the current frame and the co-located area within the previous reference frame based on DMVE criteria. In other words, for each candidate MV_i, there is a calculated SAD_1 based on DMVE criteria.

Step 3: Calculate the difference as SAD_2 between the two MBs in the two previous frames projected with the candidate MV_i as Fig.3. The previous frame F_{k-2} of the reference frame F_{k-1} is utilized. The lost MB MB(x, k) at position x of the frame F_k, is projected to the F_{k-1} with the current MV candidate, and is also projected to the F_{k-2} with the double of the MV candidate. The obtained MBs are MB(x+mv, k-1) and MB(x+2mv, k-2). We calculate the difference of these two MBs as the corresponding SAD_2 of the MV candidate. The SAD_2 can be interpreted as the measurement of the constant motion velocity model.

Step 4: The MV can be selected as the best match with the minimum SAD as follows:

$$SAD = \alpha SAD_1/\lambda + (1-\alpha)SAD_2/256 \quad (1)$$

where α means the weight factor, which varies from video contents. In our test, α is set 1/2 for the simplicity, i.e.

$$SAD = 0.5\times SAD_1/\lambda + 0.5\times SAD_2/256 \quad (2)$$

λ relates to the number of available pixels used in the calculation of SAD_1 as DMVE criteria, which varies with the position of the lost MB. Since SAD_2 is always calculated with a MB containing 256 pixels, the different weights that we impose on SAD_1 and SAD_2 mean that we normalize the difference caused by the candidate MV to pixel level. We combine the two normalized parts together as the new criteria for MV selection. In the new criteria, not only several lines of pixels that surround the entire lost MB are used as the basis of motion estimation, but also the consistency of the MVs in sequential frame is considered.

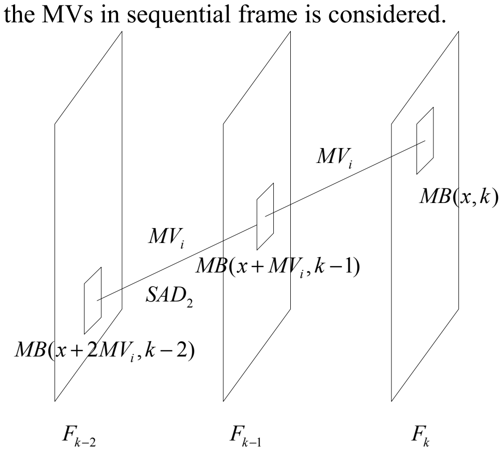


Fig. 3 correlated MB in calculation of SAD_2

Step 5: The MV selected from previous step is used as the recovered MV of the lost MB MB(x, k). The MV is then used to find a MB in the previous decoded picture which regarded as the best estimation of the lost intensity information.

3. SIMULATION RESULTS

The simulation is based on H.264 video coding standard and the reference code JM10.2 is used. Three well-known CIF sequences (Foreman, Bus, and Mobile) are used for our experiment. Each sequence is encoded with the frame structure of IPP…IPP… (No B frame inserted), The GOP is set to 12 (12 frames per I frame). A slice is encapsulated to a packet with fixed containing 50 MBs and no FMO model is used. The loss of packets is simulated using the network simulation tools for 3G mobile transmission that are generally used by JVT. Different packet loss rates, 5% 10% are tested. Since we're only considering the performance of temporal error concealment methods, the error patterns are restricted to random occurred in P frames only. To evaluate the performance of the proposed algorithm, BMA embedded in JM software and DMVE with two-line search is used for comparison. The results are shown in following tables.

TABLE I
PERFORMANCE COMPARISON IN PSNR FOR THE PACKET LOSS RATE CASE (PLR=5%) (dB)

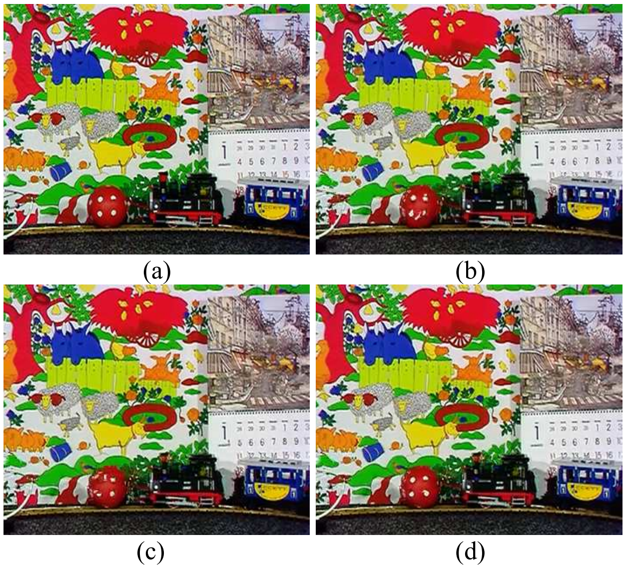
Test Seq.	BMA	DMVE	Proposed algorithm
Foreman	33.82	34.51	34.82
Bus	28.07	29.52	30.24
Mobile	28.64	30.26	30.98

TABLE II
PERFORMANCE COMPARISON IN PSNR FOR THE PACKET LOSS RATE CASE (PLR=10%) (dB)

Test Seq.	BMA	DMVE	Proposed algorithm
Foreman	31.69	31.52	33.03
Bus	25.49	26.47	27.53
Mobile	26.40	28.32	29.20

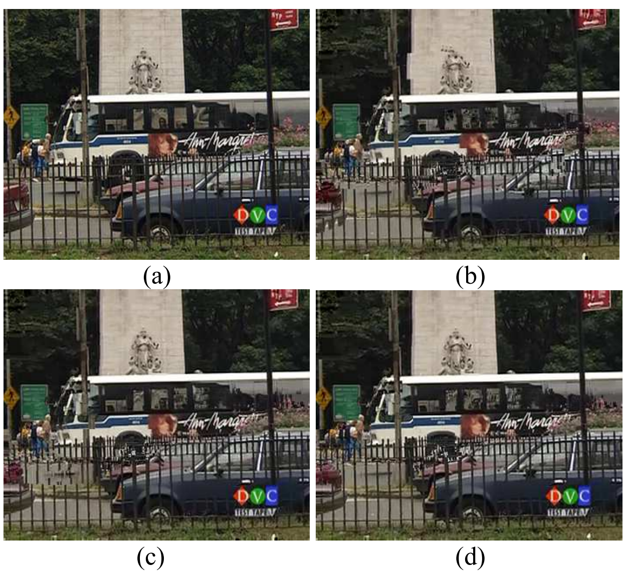
It can be seen from Table I and II that we have achieved 0.31-0.72dB improvement when the PLR is 5% and 0.88-1.51dB improvement when the PLR is 10% over the two-line based DMVE search algorithm and 1.0-2.34dB improvement when the PLR is 5% and 1.34-2.8dB improvement when the PLR is 10% over the embedded BMA algorithm.

Meanwhile the subjective improvement achieved by the proposed algorithm is also very evident. Fig.4 and 5 show pictures from two sequences used in our experiments for motion-compensated concealment based on the MV achieved from BMA, DMVE and our proposed algorithm. These figures indicate that the subjective improvement is indeed significant.



(a) (b) (c) (d)

Fig. 4 (a) Original frame. (b) Frame concealed using BMA (PLR=5%) PSNR = 25.85dB. (c) Frame concealed using DMVE (2-line search) PSNR = 27.09dB (d) Frame concealed using proposed algorithm PSNR = 28.19dB



(a) (b) (c) (d)

Fig. 5 (a) Original frame. (b) Frame concealed using BMA (PLR=10%) PSNR = 20.78dB. (c) Frame concealed using DMVE (2-line search) PSNR = 21.98dB (d) Frame concealed using proposed algorithm PSNR = 23.93dB

In Fig.4, the red ball is recovered much better in the proposed algorithm than in the BMA and DMVE algorithm. Meanwhile, there is an obvious error in the numbers in the menology in both the BMA and DMVE algorithm while the proposed algorithm recovered correctly. In Fig.5, it can be seen the BMA algorithm has some errors in recovering the monument and the baluster while the DMVE algorithm failed in recovering the baluster area. Our proposed algorithm performs much better.

5. CONCLUSION

A new TEC algorithm has been proposed which adopts the improved DMVE criterion. The new criterion considers temporal correlation and motion trajectory together. By adopting the DMVE criteria and constant motion velocity model together, a more accurate motion model for the lost area is achieved. Simulations show that the proposed technique can achieve remarkable objective (PSNR) and subjective gains in the quality of the corrupted video.

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