ENHANCING WHOLE–FRAME ERROR CONCEALMENT WITH AN INTRA MOTION VECTOR ESTIMATOR IN H.264/AVC

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ABSTRACT

The novel H.264/AVC video coding specification [1] provides a significant improvement in terms of coding efficiency compared to previous standards. In certain streaming scenarios the problem of a whole–frame loss concealment can arise when using H.264/AVC. Two different algorithms have been proposed to conceal a lost image basing on the optical flow concept. In a real streaming scenario, an encoder usually introduce some kind of intra refresh policy that can put in troubles concealment algorithms leaving gaps in the motion vector field used for reference. In this paper we discuss the advantages of introducing a motion vector estimator for such intra coded regions.

1. INTRODUCTION

Some algorithms for whole frame error concealment have been recently proposed [2], [3]. They are designed especially for trasmission of low bit-rate sequences over error prone networks; in such a situation the loss of a network unit typically involves the loss of a whole coded picture that cannot be recovered using classical concealment algorithms. We especially consider the streaming scenario, focused by baseline profile defined by the H.264/AVC specification, in which no bidirectionally predicted pictures are allowed. In section 2 we will briefly recall the basic structure of two algorithms based upon the *Optical Flow* [4]. Since they use the motion information from previous correctly received frames to reconstruct the lost picture, their efficiency increases as much as the previous motion field is complete. For this reason we introduced an additional step for each decoded frame that performs an estimation of the motion vector for each intra coded macroblock. In this way we recreate a complete motion vector field that can be better exploited by the whole–frame concealment algorithm. Moreover this proposal can be easily applied to classical concealment techniques that exploit temporal information [5], [6]. This operation can be particulary useful when some policy of forced intra refresh has been used on the encoder side. In such a situation, our tests and simulations show that the estimation of missing motion vectors for intra coded macroblocks increase the efficiency of the concealment providing a better visual quality for the reconstructed video sequence. In section 3 we describe the intra refresh policies that can be used in our H.264/AVC modified encoder and, in section 4, the solution we propose to limit their impact on whole–frame concealment algorithms.

*This work was partially supported by the Italian Ministry of Education and Research under the PRIMO (Reconfigurable Platforms for Wideband Wireless Communications) grant.

2. EXISTING ALGORITHMS FOR THE WHOLE–FRAME CONCEALMENT

The optical flow can be considered as the distribution of apparent velocities of moving objects in the image (for a detailed analisys of optical flow theory please refer to [4]). Two algorithms that exploits this concept have been recently proposed by Belfiore et al. [2] (we will refer to it as CA_P- *Concealment Algorithm on Pixels* since it works on the pixel domain) and Baccichet et al. [3] (named CA_B- *Concealment Algorithm on Blocks* since motion vector are recovered for each 4x4 block). In the following we will give a brief explanation of these solutions.

- *Concealment Algorithm on Pixels*. A "forward" motion vector is associated to each pixel of the previously decoded picture $t-1$. This forward MV field is used to "project" the reference picture $t-1$ onto the lost frame t into the pixel domain. Some pels of picture t can still be empty after this "projection" and are reconstructed by mean of a median filtering operation.

- *Concealment Algorithm on Blocks*. It uses the same basic idea of the CA_P solution but it works in a symmetric perspective. In fact, it does not project the picture $t-1$ onto the lost one t but it tries to give an estimation of the lost motion vector field for image t to perform a simple motion compensation. In practice, for each pixel of frame $t-1$, it copies the inverted MV of the corresponding block onto the pixel it points to in frame t. Then a motion vector is estimated for each 4x4 block of the lost picture. If some blocks are left empty, missing motion vectors are recovered performing boundary matching and choosing among a set of candidates.

3. INTRA REFRESH POLICIES IN H.264/AVC

The JVT reference model of the H.264/AVC video encoder includes the possibility to decide at configuration time the percentage of macroblocks for each frame that will be forced to be intra coded. This is an error resilience technique adopted to limit the propagation of errors over consecutive motion compensated pictures. We modified the reference model in order to make it possible to use intra refresh policies at macroblock or slice level. In the first case, macroblocks to be intra coded are chosen in a pseudo random manner; in the latter one, the frame is partitioned into differents slices and intra coded macroblocks are located consecutively inside one or more slices. These two policies have been used in our simulations to force a complete refresh every twelve pictures. We want to emphasize how they lead to an intra coding of regions of the picture where motion information could potentially be available. Our simulations have shown that, when an intra refresh policy is in use (as it happens in real scenarios), the performances of a whole–frame error concealment algorithm get worse. This is the reason why we thought of introducing an estimator of the lacking motion information for each intra coded macroblock of the decoded frame.

4. PROPOSED SOLUTION

The algorithm (we will refer to it as *IntraMVRec*) is applied to each decoded frame, as an additional step after the error concealment and deblocking filter steps. It carries out an estimation of missing motion vectors for intra coded macroblocks using motion information coming from spatial and temporal neighbouring ones. Specifically, a set of 6 predictors is determined for each considered macroblock. SAD (*Sum of Absolute Differences*) over all the pixels is the criterium for choosing the one that gives the best approximation.

The proposed solution operates in a iterative manner:

- First it searches for intra coded macroblocks having at least four motion compensated neighbours and tries to give an estimate of the motion vector for them.
- If there are still unprocessed intra MBs after the first scan, a second one is performed, considering as valid neighbours even recovered ones.
- Finally, if intra motion vectors recovery is not completed yet, we repeat the iteration from the first step decrementing the initial threshold of four neighbours by one unit and so on.

4.1. Predictors

Predictors are chosen trying to exploit temporal and spatial correlation that exists among the motion vectors of continous regions of an image. Spatial predictors consider information coming from the inter coded macroblocks adjacent to the considered one. This is a valid solution when a single macroblock has been forced to be intra coded, since neighbours are usually available. On the other hand, when intra refresh occurs at slice level, several contiguous MBs are forced to an intra coding. In this case it is necessary to consider even motion information coming from the previously decoded frame.

All the six implemented predictors (except one) operate at macroblock level; in this way the same estimated motion vector is assigned to each 4x4 subblock partition of the macroblock. As we have verified in fact, performing the estimate at 4x4 subblock partition level can bring sometimes to a motion vector field that do not represent the effective motion of the sequence. For this reason we perform a median filtering operation on the estimates and we assign the same result to each subblock partition of the macroblock. In order to obtain, as result of the filtering operation, a real vector (i.e. belonging to the set of motion vectors to be filtered), we evaluate with a median filter the x and y components of each vector indipendently, obtaining a temporary vector $(\text{med}_x, \text{med}_y)$. Finally we choose the MV to assign as the closest one to $(\text{med}_x, \text{med}_y)$.

In the following, we will briefly describe the predictors used by the algorithm, considering $\text{MB}(x, y, t)$ as the intra MB to be processed at column x, row y in the frame t.

- *Upper spatial predictor.* Given by the median of all the motion vectors present in $\text{MB}(x, y-1, t)$.
- *Lower spatial predictor.* Obtained by the median filtering of all the motion vectors present in $\text{MB}(x, y+1, t)$.

- *Neghbouring spatial predictor.* This predictor requires that MB(x, y, t) presents at least two inter coded neighbors. It assigns to each 4x4 subblock partition of the intra coded macroblock the MV of the nearest subblock among those belonging to the neighbouring MBs available. Working at subblock level instead of doing the median of all motion vectors offers better results in this case.

- *Temporal predictor.* The predictor is given by the median of all the motion vectors present in MB$(x, y, t-1)$, if available.

- *Projected motion vectors predictor.* In this case we exploit the concept of *Optical Flow* to recover motion information. The predictor is given by the median of all the motion vectors that, projected from frame $t-1$ to frame t, fall inside the considered macroblock MB(x, y, t).

- *Null vector predictor.* Null vector is assigned to all 4x4 block of MB(x, y, t).

5. SIMULATION RESULTS

For our simulations we coded different well known CIF sequences at several quantizer levels, introducing for each of them two different intra refresh policies (pseudorandom allocation of intra MBs and complete intra slice). In order to test the effectiveness of our solution, we simulated the loss of a picture in the sequence removing from the stream the slices containing that frame. Then we measured the PSNR for the decoded sequence. We repeated these operations simulating the loss of each frame of every considered video sequence. As we have verified, the gain achieved on the reconstructed image using our technique keeps almost constant over subsequent (correctly received) ones (see Fig. 1). In force of this observation we can consider the average PSNR value of concealed frames as a measure of *IntraMVRec* performances. These values are reported in Table 1 for Table Tennis, Foreman, Coastguard sequences coded at 15 frames per second and decoded using both *CA*$_B$ and *CA*$_P$ algorithms to conceal lost pictures.

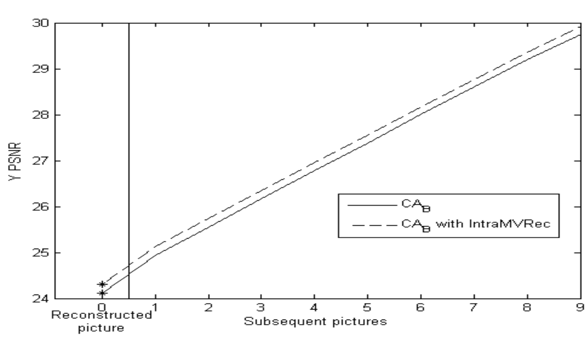

Fig. 1. Foreman results applying the *CA*$_B$ algorithm

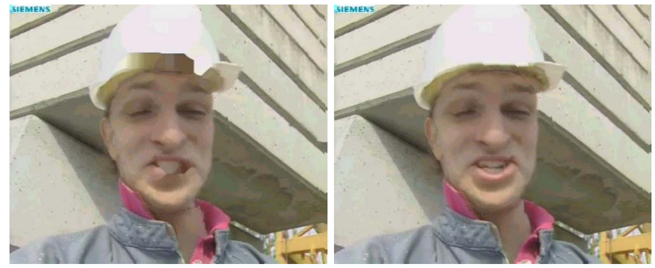

Fig. 2. Example of reconstructed images using the proposed solution with *CA*$_P$.

As the gain achieved using our improved concealement changes depending on the lost frame, values reported in Table 1 are indicative of the average behaviour over the whole sequence. On the other hand, performances of this technique can be significant even versus some whole frame loss rate, as shown in Table 2 for Table sequence. In this case, a certain percentage of frames are lost in a pseudo random manner and then PSNR is evaluated for the whole decoded sequence. Values reported in Table 2 represent the gain obtained when lost frames are concealed with *CA*$_P$ with *IntraMVRec* versus the case in which *CA*$_P$ without *IntraMVRec* is used.

We also want to point out that the results reported are relative to the whole image while the *IntraMVRec* procedure affects only intra coded regions in the reference image. In Fig. 2 and Fig. 3 we report two examples showing that, even if the PSNR gain over the whole picture could appear marginal, the improvement in the visual quality perceived can be very significative. In Fig. 2 one frame of the Foreman sequence has been reconstructed using the *CA*$_P$ without (on the left) and with *IntraMVRec* solution. It is possible to see as the artifacts on the helmet and near the mouth

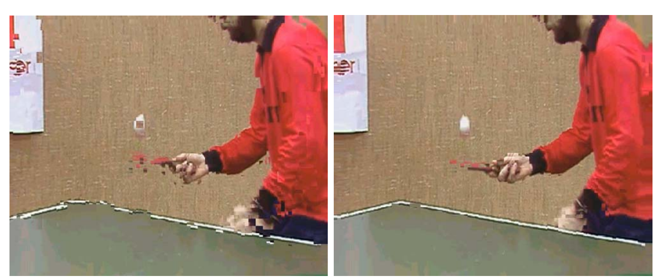

Fig. 3. Example of reconstructed images using the proposed solution with *CA*$_B$.

Table 1. Comparison of concealment performances

Slicing Policy	Sequence	CA_P	CA_P with IntraMVRec	CA_B	CA_B with IntraMVRec
CIF RAND 12	Coastguard QP-23	26.409	26.654	25.234	25.600
	Coastguard QP-31	25.852	26.049	25.306	25.570
	Coastguard QP-39	24.387	24.519	24.231	24.389
	Foreman QP-23	24.715	25.007	24.416	24.631
	Foreman QP-31	24.378	24.652	24.113	24.310
	Foreman QP-39	23.757	23.965	23.552	23.677
	Table QP-23	26.435	26.724	25.756	25.871
	Table QP-31	25.751	26.026	25.225	25.351
	Table QP-39	24.519	24.712	24.193	24.329
CIF SLICE 12	Coastguard QP-23	25.389	26.609	25.159	25.542
	Coastguard QP-31	24.938	26.016	25.261	25.546
	Coastguard QP-39	23.783	24.520	24.155	24.369
	Foreman QP-23	24.079	24.887	24.252	24.510
	Foreman QP-31	23.856	24.619	24.048	24.270
	Foreman QP-39	23.310	23.945	23.502	23.680
	Table QP-23	25.384	26.702	25.727	25.861
	Table QP-31	24.849	26.020	25.187	25.332
	Table QP-39	23.942	24.716	24.187	24.324

Table 2. PSNR gain versus frame loss rate for CA_P algorithm when IntraMVRec is used.

Slicing Policy	Sequence	1%	2%	5%	10%
CIF RAND 12	Table QP-23	0.050	0.198	0.339	0.430
	Table QP-31	0.041	0.053	0.187	0.355
	Table QP-39	0.019	0.036	0.109	0.190
CIF SLICE 12	Table QP-23	0.303	0.549	0.988	1.288
	Table QP-31	0.231	0.461	0.839	1.107
	Table QP-39	0.163	0.265	0.496	0.791

of the man disappear when using our proposed solution.

In Fig. 3 frames are taken from Table sequence and have been reconstructed using the CA_B without (on the left) and with the IntraMVRec solution. Even in this case many artifacts around the hands of the man and on the edges of the table are eliminated when using *IntraMVRec* .

6. CONCLUSIONS

In this paper we have proposed a solution that can significantly improve the performances of a whole frame error concealment algorithm or a temporal error concealment solution in general. We reported results in terms of PSNR values that confirm the effectiveness of the proposal and examples highlighting the improvement obtained in the visual quality of reconstructed images.

7. REFERENCES

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