

Low-Complexity Mobile Video Error Concealment Using OBMA

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Abstract- A low-complexity error concealment technique called the outer boundary matching algorithm (OBMA) for mobile video applications is studied extensively in this work. The OBMA technique is shown to provide an excellent trade-off between the complexity and the quality of concealed video for a wide range of test video sequences.

I. INTRODUCTION

As video coding technologies and standards advance, wireless video applications have become more and more popular in portable consumer electronics, including mobile TV and 3G cellular phones. One common problem in transmitting compressed video over unreliable channels in mobile and/or wireless environments is video quality degradation due to transmission errors. To address this problem, the error concealment (EC) technique has been studied extensively in the last 15 years. EC is a post-processing technique employed at the decoder side as shown in Fig. 1. The basic idea is to recover the lost data from decoded video by exploiting its spatial/temporal correlation. Recent developments in EC tend to utilize unique features provided by the new video coding standard, such as the variable block size and multiple reference frames in H.264/AVC, to improve video quality. However, the computational complexity of most proposed EC methods from academia is too high to be practical in mobile applications.

We investigate a low complexity EC algorithm which can however offer excellent performance in this work. The boundary matching algorithm (BMA) has attracted a lot of attention due to its low complexity. Here, we examine a modified BMA called the outer boundary matching algorithm (OBMA). Even though BMA and OBMA are designed under a very similar philosophy, we observe that OBMA outperforms BMA by a significant margin (typically, 0.5dB or higher) while maintaining the same level of complexity. However, such a major performance gap has not yet been well analyzed in the literature. In this work, we offer more insights into OBMA and provide extensive experimental results to show its usefulness.

II. BMA AND OBMA ERROR CONCEALMENT METHODS

BMA is recommended as a non-normative temporal concealment in H.264 [4]. Under the assumption of a smooth transition between the boundary of the lost macroblock (MB) and its neighboring MBs, BMA selects the best motion vector (MV) to conceal lost MB from a set of candidate MVs that includes the zero MV and all eight neighboring MVs labelled by MV0, MV1, ..., MV6 and MV7

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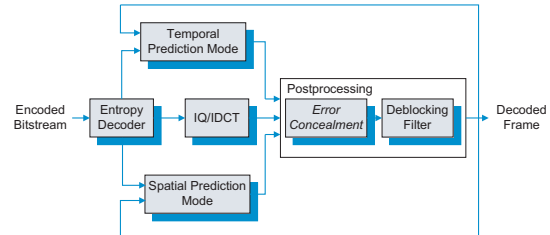


Fig. 1. The block-diagram of a decoder with an EC module.

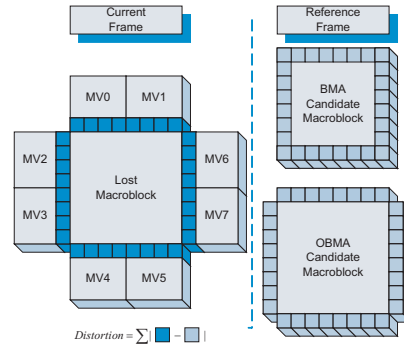


Fig. 2. Distortion computation in BMA and OBMA algorithm

as shown in Fig. 2. BMA calculates the mean absolute difference (MAD) between the boundary of neighboring MBs and the inner boundary of each candidate MB created by backward tracing the corresponding MV to the reference frame. OBMA, also known as the decoder motion vector estimation (DMVE) method [1], computes MAD using the boundary of neighboring MBs and the outer boundary of the candidate MB as shown in Fig. 2.

Both BMA and OBMA choose the candidate MV that has the lowest MAD to conceal the lost MB as

$$D_n^{BMA} = MAD(P^N, P_n^I), \quad (1)$$

$$D_n^{OBMA} = MAD(P^N, P_n^O), \quad (2)$$

$$n_{opt} = \arg \min_n (D_n), \quad n = 0, 1, \dots, 8, \quad (3)$$

where D_n^{BMA} and D_n^{OBMA} correspond to BMA's and OBMA's distortions of the n^{th} candidate MB, P^N is a set of all boundary pixels of neighboring MB, P_n^I and P_n^O are sets of all inner and outer boundary pixels of the n^{th} candidate MB, respectively, and

$$MAD(A, B) = \frac{1}{N} \left| \sum_{\forall i; q_i \in A} q_i - \sum_{\forall j; q_j \in B} q_j \right|,$$

where N is the size of sets A and B . Despite the great similarity in BMA and OBMA computations, OBMA is however motivated

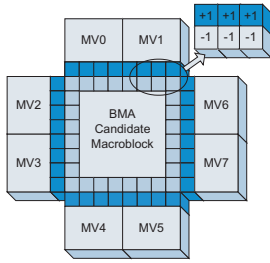


Fig. 3. Relationship between the BMA matching function and the gradient-based edge detectors

by a different principle. That is, it exploits the linear translational model of a matching MB of size 18×18 and uses all pixels located at the block boundary as partial matching. It does not demand smooth boundary transition as BMA. If there is an edge traversing across the block boundary, BMA often fails while OBMA still function well.

To illustrate the reason why OBMA outperforms BMA better, we consider an example given in Fig. 3. The BMA matching function behaves like the horizontal and vertical gradient-based edge detectors with simple differences. In other words, BMA penalizes any edges that traverse through block boundaries. Besides, these edges violate the BMA underlying assumption since they form an uneven surface along the block boundary.

III. OTHER DERIVED LOW COMPLEXITY ERROR CONCEALMENT METHODS

The other four low-complexity EC techniques under our consideration are: zero motion vector (ZMV), average motion vector (AMV), overlapped motion vector (OMV) and its modified version (OMV+). ZMV and AMV are known as one of the lowest complexity EC techniques. ZMV uses the corresponding MB in the reference frame for concealment while AMV reconstructs the lost MB based on the MV obtained from averaging all neighboring MVs. OMV restores the lost MB by combining three intermediate subblocks obtained from the side match criterion and the MVs of vertically and horizontally adjacent neighboring subblocks. The side match criterion used in OMV is essentially a modified version of BMA's matching function. In [3], OMV utilizes a weighting matrix for subblock merging to produce the concealed MB with less blocky artifact along the boundary of subblocks. However, simple averaging is used in our work since it requires less complexity and the deblocking filter in the decoder can proficiently remove some of these effects. OMV+ is similar to OMV. Their main difference is that OMV and OMV+ adopt modified BMA and OBMA matching functions, respectively.

IV. PERFORMANCE COMPARISON AND DISCUSSION

We apply all six EC algorithms discussed in Secs. II and III to three video sequences (City, Crew and Harbour) under QCIF (176×144), CIF (352×288) and 4CIF (704×576) resolution. For each sequence, the first 100 frames are used and encoded with IPPP format. The error is modeled as uniformly distributed random with 10% MB loss ratio. For each case, 10 error patterns are employed and average results are reported in Fig. 4. The encoder and decoder module are based on H.264/AVC reference software version 11.0 [2].

Both ZMV and AMV may have the lowest complexity but they perform significantly poorer than other EC techniques in all

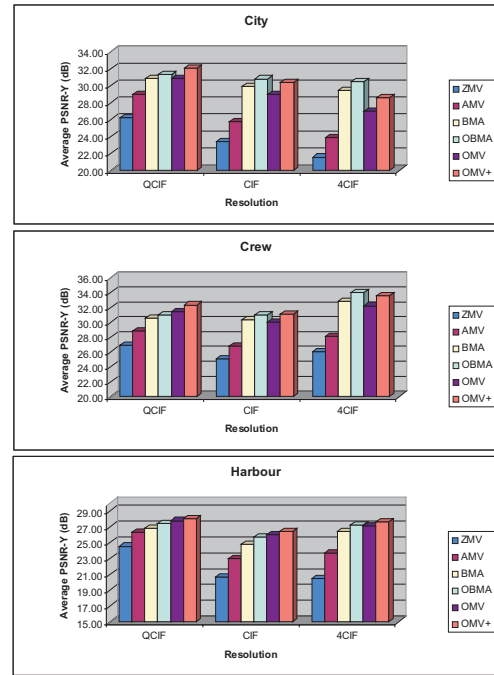


Fig. 4. Performance comparison of six EC algorithms.

test cases. OBMA performance is approximately 0.51, 0.82 and 1.01 dB better than BMA in QCIF, CIF and 4CIF sequences, respectively. Performance of BMA and OBMA is getting better by comparison for higher video resolutions since they tend to have better spatial features in the matching process. In the low resolution case, OMV yields the same level of quality as OBMA but its performance suffers from ambiguity introduced by the averaging operation. With the modification, OMV+ gains approximately 0.80, 0.96 and 1.13dB improvements from OMV in QCIF, CIF and 4CIF sequences, respectively. This enhancement is mainly due to the performance boost from the use of the OBMA-like matching function.

V. CONCLUSION

OBMA is suitable for practical mobile video applications since it has an excellent trade-off between complexity and concealed video quality. Besides, it can be used to enhance other EC techniques that rely on the block-matching procedure as observed in the proposed OMV+ algorithm.

VI. REFERENCES

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