ENHANCED ERROR CONCEALMENT FOR VIDEO TRASMISSION OVER WLANs

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ABSTRACT

Video transmission over wireless local area networks (WLANs) using time sensitive protocols like UDP is prone to packet erasures taking place in adverse channel conditions. Use of error concealment at the decoder is necessary in such cases to prevent error induced artefacts from rendering the affected video frames visibly intolerable. This paper presents error concealment methods developed within the EU FP6 WCAM project for an H.264 decoder that when coupled with error resilient encoding can successfully mask the effects of such errors. The performance of the developed error concealment approach is demonstrated using error data collected through real IEEE 802.11b/g WLAN measurements and is shown to be superior to that of the reference software decoder (JM).

1. INTRODUCTION

Streaming of video over a wireless channel usually involves the use of either the TCP/IP or UDP/IP protocols as the intermediate network/transport between the physical and application layers. The UDP protocol facilitates the transfer of time-sensitive video data, but its use is associated with packet erasures when channel conditions are not favourable. To avoid a large drop in video quality at the receiver due to intra- and inter-frame propagation of such errors a certain amount of error resilience at the encoder and the use of some form of error concealment at the video decoder is necessary.

Error concealment methods [1][2] estimate lost information by employing the correlation that exists between a missing macroblock (MB) and the temporally and spatially adjacent ones. They can be classified in two categories. Temporal concealment methods estimate lost motion vectors and then use these for motion compensated temporal replacement of the lost MBs. Spatial concealment methods rely on spatially adjacent macroblocks for estimating missing pixels usually through an interpolation process.

Although not normative, the reference software decoder (JM 8.0) implements both spatial and temporal error concealment for missing intra and inter coded macroblocks [3]. The spatial concealment (employed only for lost MBs in IDR or I frames) is based on the method described in [4] which replaces missing pixels with weighted averages of boundary pixels in adjacent MBs. Temporal concealment (employed solely for lost MBs in P or B frames), is implemented based on the boundary matching algorithm (BMA) [5] which predicts one missing macroblock MV out of a list of candidate MVs coming from 4-neighbouring MBs (or 8x8 blocks of these) and including the zero MV. The MV that results in the smallest boundary matching error (BME) is then used for motion compensated replacement of the missing pixels from a previously decoded frame.

This paper presents enhanced error concealment methods developed within the EU FP6 WCAM project that offer improved performance compared to the JM decoder. The WCAM project addresses wireless video transmission trials for two types of application, remote surveillance and entertainment. Planned demonstrations include transmission of H.264 coded video material over 802.11b/g networks [6] with UDP/IP being employed as the transport and network layers over unicast and multicast links. The concealment methods described in this work are compared with those employed by the JM decoder using IEEE 802.11 b/g error patterns collected at the WCAM trial locations using the above operating parameters [7][8][9].

The structure of the paper is the following. First the H.264 error resilience options employed at the encoder are described. Sections 3 and 4 describe proposed temporal concealment methods for P and I frames respectively. Section 5 states the need for concealment mode selection and describes the algorithm used in this work. Section 6 shows results using measured IEEE 802.11b/g error patterns. Finally conclusions finish this paper.

2. ERROR RESILIENCE

Error resilience mechanisms are introduced at the encoder in order to make the transmitted video data more resilient to potential errors and/or to facilitate (improved) error concealment at the decoder. A number of error resilience options are supported by H.264 including the use of slices and flexible macroblock ordering (FMO) [10][11].

Slices interrupt the in-picture coding mechanisms thus limiting any spatial error propagation to the macroblocks of the affected slice only, and through slice headers serve as synchronisation points. As a result the use of slices is a prerequisite for most error concealment methods since it can prevent the loss of entire pictures. FMO allows the assignment of MBs to slice groups in orders other than the normal raster scan order based on a macroblock allocation map. The available map types include, amongst others, dispersed and interleaved macroblock allocation. Both can lead to improved concealment performance (especially at higher packet error rates or in the presence of bursty errors) by increasing the likelihood of having correctly received MBs adjacent to the ones lost.

For all the concealment results presented in this work FMO(dispersed) and slices were used. Slices sizes are stated as necessary and are of specific number of MBs or bytes. Intra refresh coding in the form of regular IDR frames has also been employed in order to prevent increased temporal propagation of errors. Finally constrained intra prediction was used to avoid errors propagating temporally to intra coded MBs.

3. TEMPORAL CONCEALMENT FOR P FRAMES

A number of temporal concealment methods exist for use with standard video decoders [3] [12]-[16]. In order to create an enhanced temporal concealment approach, a model was constructed that describes the steps most of them follow. This model is shown in Figure 1. First a list of MV candidates is formed for replacing the MV(s) missing from the lost MB. Each one of the candidates is then tested using a matching error measure that determines which one offers the best possible replacement for the lost MB. Having selected the replacement MV some methods proceed to what is described here as an enhancement step. This can be overlapped block motion compensation (OBMC), i.e. replacement of the lost MB with pixels coming from more than one previous MBs and/or motion refinement whereby the selected replacement MV (or other candidate MVs) is used as a starting point for a motion estimation process that looks for better MV replacements using the same matching measure.

We have conducted a performance analysis that demonstrates how each component of the model in Figure 1 affects concealment. For the list of MV candidates apart from the zero MV and 4-neighbours, we have tested the MV of the collocated MB in the previous frame, the 8-neighbours and the average and median of all adjacent MBs. As a matching measure we have tested the boundary matching error (BME) used in the JM decoder (the sum of absolute differences - SAD - between pixels on the boundary of the replacement reference MB and the boundary of the MBs adjacent to the damaged one); the external boundary matching error (EBME) suggested in [12][15] (the SAD between the external two-pixel-wide boundary of the MBs adjacent to the damaged MB and the same external boundary of the MBs adjacent to the candidate replacement reference MB); and finally the weighted external boundary matching error (WEBME) [14], similar to EBME with the boundary being 4 pixels wide and with raised cosine weights being used for calculating the distortion. In terms of enhancements, overlapping was implemented according to[14] (i.e. using 4 prediction signals and the raised cosine matrix as the weighting matrix) and motion refinement was implemented following a 3-step search approach to avoid a large increase in complexity. For the analysis three CIF sequences (“Foreman”, “Bus”, “Stefan”) were coded with H.264 (JM 8.0) at 1Mbits/sec using 3 reference frames with I and P pictures only (one IDR frame was used every 90 frames).

Each sequence was encoded using FMO-dispersed and 4 different slice sizes equal to 22, 33, 66 and 99 MBs (1, 1.5, 3 and 4.5 rows respectively) Random packet errors (slice erasures) were introduced to each of the coded clips at rates of 0.1% 0.5% 1% 2% 4% and 10%. For each packet error rate and each clip there were 10 different error sequences. Note that errors were not introduced in IDR pictures to avoid the use of spatial concealment. The PSNR results presented (apart from motion refinement) are averaged over 10 clips per slice size, over 4 slice sizes and over the 3 test sequences (120 clips for each PER).

Figure 2 shows the difference in performance when the respective MVs are added to a candidate list which already includes the 4-neighbours of a missing MB using the EBME. One can see from the graphs that the average and median MVs offer limited improvement in performance, while the previous frame MV (i.e. the MV of the collocated MB in the previous frame) improves the results (note that without FMO the 8-neighbours were found to be useful). Including all the candidates gives a further small improvement compared to the best single-candidate performance. Figure 2 also includes overlapping results (OBMC) which indicate that the use of overlapping is beneficial to concealment, especially at higher packet error rates. Figure 3 shows how changing the matching measure affects the results when all candidates are used. It is clear that changing to an external boundary match improves the results significantly on average (close to 1 dB at high PERs). EBME is preferred due to its smaller complexity. The performance of the enhanced temporal concealment method resulting from this study and adopted for the WCAM H.264 decoder is shown in Figure 4 (with & without FMO encoding).

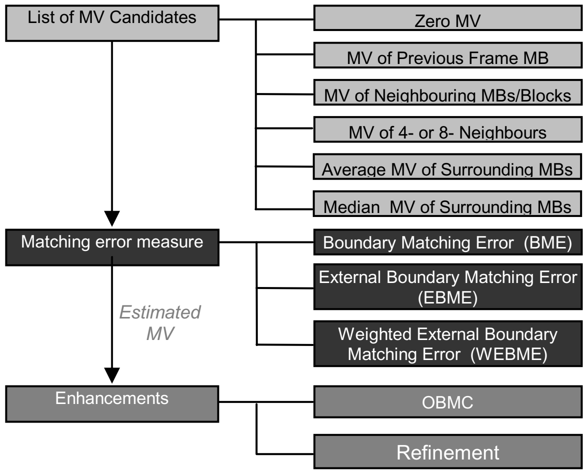

Figure 1: Typical temporal concealment steps

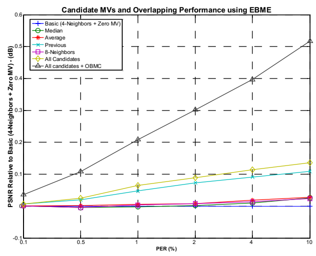

Figure 2: MV candidate and overlapping evaluation.

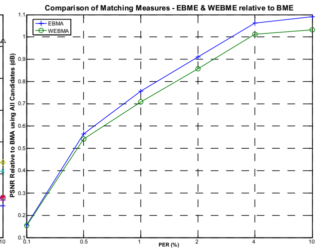

Figure 3: Matching measure evaluation

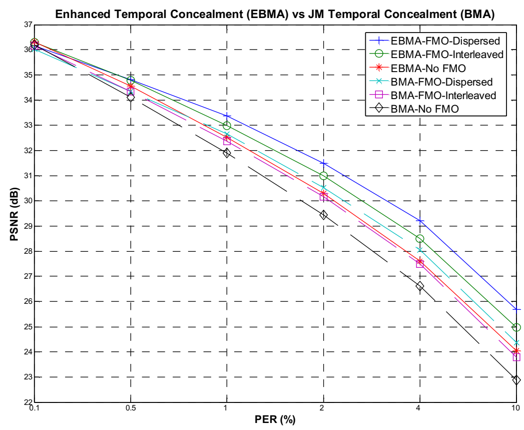

Figure 4: Temporal concealment results

4. TEMPORAL CONCEALMENT FOR I FRAMES

Because IDR (and generally I) frames lack motion information errors tend to be concealed using spatial methods. However when temporal correlation is high (e.g. in sequences with uniform motion) the use of temporal concealment would be preferable. Furthermore with IDR frames occupying more bytes in the coded bit stream it is more likely for them to be corrupted, thus increasing the need for good concealment of lost IDR MBs at the decoder.

Based on the model of Figure 1 the major problem in the case of IDR frames is how to form the motion vector candidate list. One obvious choice is the zero MV (temporal copying) [17]. We additionally employ the collocated MB in the previous frame (when not intra coded) and its 8-neighbours in a similar manner to P-frame concealment. Previously concealed adjacent MBs of the lost IDR MB are also used. Due to the shortage of good motion vector candidates in IDR frames we have also used motion estimation/refinement for improving temporal concealment in such frames. Motion estimation is effectively refinement of the zero MV. Refinement is applied to the selected replacement MV as described in the previous section.

The benefit of applying our temporal concealment method to IDR frames compared to the spatial concealment of the JM decoder is illustrated in Figure 5 for 'foreman' encoded at 1Mbits/sec with 1 IDR frame every 30 frames, a slice size of 66 MBs and FMO-dispersed mode on. Errors are introduced in both IDR and P frames with P frame errors being concealed using identical temporal concealment. IDR frame errors are either concealed temporally as described before or spatially as in the JM decoder. One can see the difference in visual quality on the depicted frames (IDR frame 30 is shown) and in PSNR performance on the plot below. (IDR frames 30 and 90 were damaged). The average PSNR was 34.61dB for the spatial concealment case and 36.51 dB for the temporal one.

5. CONCEALMENT METHOD SELECTION

Temporal concealment usually leads to superior results compared to spatial concealment, as already shown for the case of IDR frames. However for frames where scene changes occur or very high or irregular motion takes place spatial concealment might be preferred and the decoder should be able to choose the right concealment mode for each MB. The method we use is based on that of [17] where temporal activity (measured as the prediction error in the surrounding MBs) and spatial activity (measured as the variance of the same surrounding MBs) are used to decide which concealment mode will be used for replacing the missing MB (spatial if spatial activity is smaller, temporal otherwise).

6. RESULTS WITH 802.11b/g PACKET LOSSES

Measured packet loss data have been collected at the WCAM trial site using two laptops equipped with commercially available IEEE 802.11b/g cards and connected in an ad-hoc network (server - client). A pre-encoded H.264 sequence at a rate of 1-2 Mbits/sec was used as the source for the WLAN transmissions. with UDP or TCP packets being sent to the client via the 802.11 modem over unicast links (Figure 6).

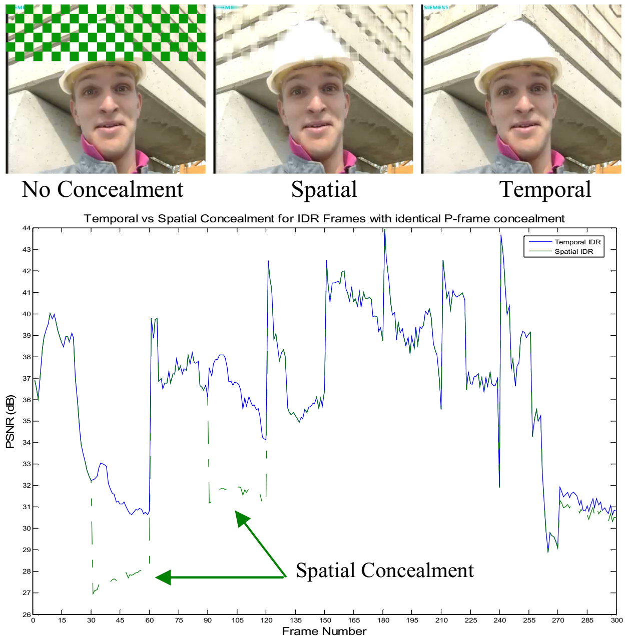

Figure 5: Temporal concealment for IDR frames

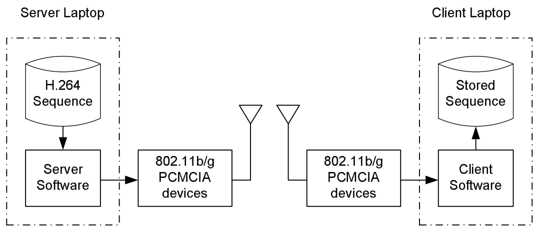

Figure 6: Measurement hardware configuration.

At the client the received packets were passed up through the protocol stack. Using a WCAM developed client software [7] a range of parameters were logged for each packet. Both static and mobile (route) measurements were conducted. The results presented are for sequence 'Hall' (repeated 10 times) with UDP packets (and slices) of 1200 bytes based on data from mobile measurements. The results are presented as frame by frame PSNR plots for the error-free case (EF), the H.264 reference decoder case (AEC) and the enhanced error concealment one (EEC). The average PSNR values for the frames included in the graph of Figure 7 were 40.15dB for the error free case, 31.51dB for the non-concealed case (not shown), 38.48dB for the AEC decoder case and 39.18 dB for EEC. The PSNR values for the reconstructed frame shown in Figure 8 were 42.57 dB, 31.9 dB and 38.36 dB for EF, AEC and EEC respectively. PSNR values for the frame of Figure 9 in the same order were 41.33 dB, 34.9 dB and 37.33 dB.

7. CONCLUSIONS

In this paper enhanced error concealment methods for H.264 decoders were described. Use of such methods can lead to better video quality at the receiver in the presence of errors compared to the method offered by the JM decoder. Results demonstrating the above have been presented using measured IEEE 802.11b/g error patterns.

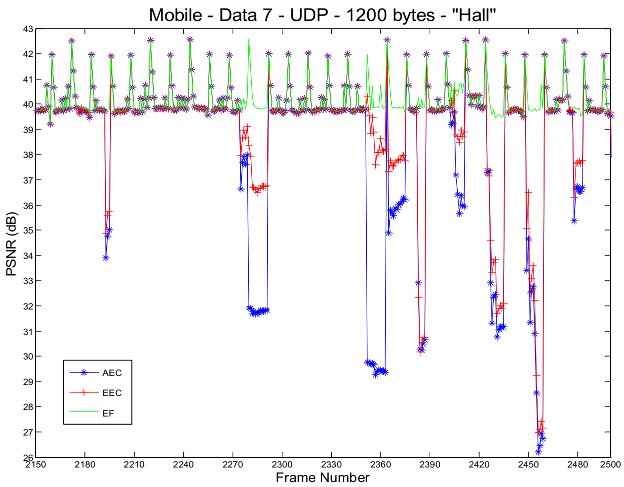

Figure 7: Mobile PSNR results for part of the "Hall" sequence.

Figure 8: Detail from frame 2280 (IDR) : error free (1st) corrupted (2nd), AEC concealed (3rd), EEC concealed (4th).

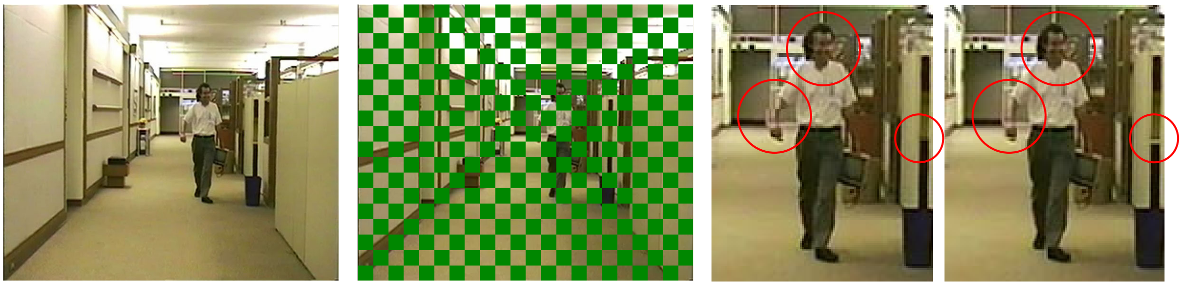

Figure 9 Frame 2365 (P) of sequence "Hall". Left-Error free; Middle left-Corrupted; Middle right-AEC (Detail); Right-EEC.

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