Content-Aware Intra-Refresh for Video Streaming over Lossy Links

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***Abstract*— *Insertion of intra-coded macroblocks (MBs) is a means of mitigating temporal error propagation in mobile video streaming using an H.264/AVC codec. This paper proposes that the insertion of a cyclic line of such intra-coded MBs can give considerable quality gain for less-active video sequences rather than the more common periodic insertion of intra-coded frames, which in its turn is shown to be favorable for more-active sequences. The paper finds that randomized insertion of intra-refresh MBs is always less suitable than a cyclic line of intra-coded MBs. The results are relevant to choice of content when streaming to/between smartphones.*

I. Introduction

Video streaming to or between smartphones may take place over bandwidth-restricted and lossy links. The restriction in capacity discourages periodic Intra-coded (I)-frames, because of their size, but the presence of all predictively-coded (P)-frame bitstreams (apart from an initial I-frame) runs the risk of unstoppable temporal error propagation. Moreover, the substantial removal of temporal redundancy in an H.264/AVC (Advanced Video Coding) codec results in video streams which are sensitive to transmission errors. Periodic I-frames are the normal method of resetting a sequence to prevent ongoing temporal error propagation. However, this paper proposes the insertion of a cyclic intra-coded line of macroblocks (MBs) on a per-video frame basis as a better way to mitigate error propagation *if* less-active video sequences are transmitted over wireless or other 'lossy' links. Earlier work with legacy codecs such as H.263 [1] also considered intra-refresh issues. For more-active sequences (ones with substantial inter-frame motion), periodic insertion of I-frames is still preferable. Furthermore, results show that H.264/AVC's randomized insertion of intra-coded MBs is by no means better than using a cyclic intra-coded line. The results have implications for choice of content when streaming to smartphones.

The benefit for less-active sequences arises from the fact that when using periodic I-frames and in the event of the loss of any of the slices of those frames, spatial interpolation is employed to conceal lost pixels. Spatial interpolation is not as effective as the motion-copy error concealment available to conceal lost slices from inter-coded P-frames. Motion-copy error concealment is able to select from received slices in previous frames, whereas spatial error concealment copies from nearby slices within the same frame without taking into account intervening motion between the current and previous frames. Figure 1.a shows a concealed slice in an I-frame

Fig. 1. a) Concealed slice in an I-frame b) Concealed slice in a P-frame

in which interpolation is used, while Figure 1.b shows a concealed slice in a P-frame in which motion-copy error concealment is performed which results in a better image quality.

For intra-refresh MBs to clean errors effectively, constrained intra prediction (CIP) should be enabled to prevent using inter-predicted samples for intra prediction. However, random scattering of intra MBs adds an extra coding penalty when CIP is enabled. For this purpose, cyclic lines of intra-coded MBs are a better alternative to gradually cleanse the stream. If there are N lines per frame then in the worst-case a complete refresh takes place within $2N - 1$ frames [2].

Activity-levels within a video sequence can be detected manually by observation of a sequence, or through knowledge of the genre, or automatically using the average of the absolute values of motion vectors. The paper now shows the advantage of using an intra-coded line for less-active video sequences over using periodic I-frames or random insertion of intra-coded MBs.

II. Methodology

To evaluate the performance of different intra-refresh schemes, 300 frames of the well-known test sequences *Hall*, *Paris*, *Stefan*, and *Soccer* in Common Intermediate Format (CIF) (352 288 pixels/frame) were coded at 30 frames/s. The first two of these sequences are less-active than the latter two, as can be seen from Table I which shows the average absolute value of motion vectors for the tested sequences.

For each test sequence, four versions were coded using the JM 15.1 reference software for H.264/AVC operating in its Baseline profile. The Baseline profile is specialized for mobile devices, omitting more computationally demanding features. The first stream was coded without any forced intra-refresh (*no-I*). The second was coded with a top to bottom cycling intra-coded line (*cyc-I-line*), that is a row of 22 MBs for CIF.

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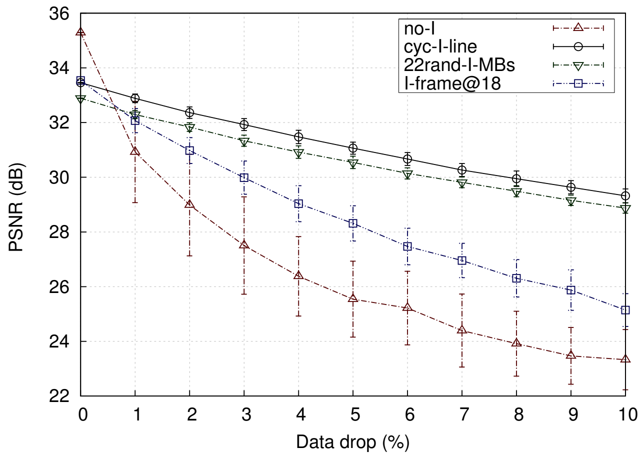

Fig. 2. PSNR vs. percentage video data loss for *Paris* test sequence.

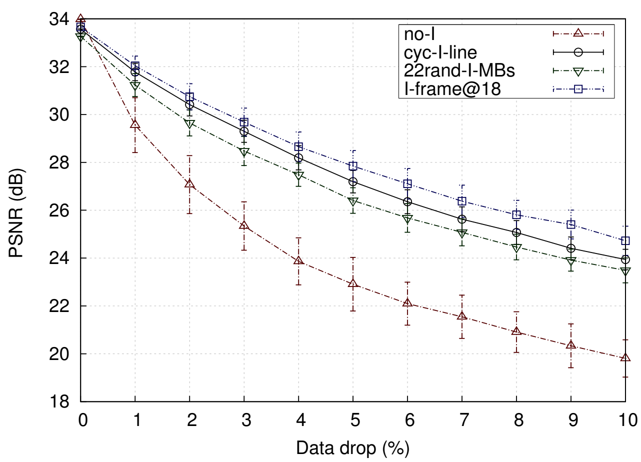

Fig. 3. PSNR vs. percentage video data loss for *Soccer* test sequence.

The third was coded with 22 randomly inserted intra-coded MBs (*22rand-I-MBs*) per frame. The last stream was coded with periodic I-frames inserted every 18 frames (*I-frame@18*) to achieve a refresh rate equivalent to 22 MBs/frame (as there are 18 rows of MBs in a CIF frame).

Packet sizes were limited at the encoder to 1 kB and packed using H.264/AVC's Real-Time Protocol (RTP) packetization mode. Constrained intra prediction was enabled and a single reference frame was used, as this limits the error introduced when using multiple reference frames in conjunction with intra-refresh MBs [3]. The sequences were constant bitrate (CBR) coded with a modest target rate of 500 kbps.

III. Experimental Results

Figures 2 and 3 show the objective video quality (peak signal-to-noise ratio (PSNR)) for *Paris* and *Soccer* test sequences when subject to uniform random losses. Each point is the average PSNR of more than 50 runs with the error bars representing the standard deviation from the mean. The relative compression overhead of different intra-update schemes is indicated by lower objective video quality at zero loss. It can be seen that at zero loss, the stream coded without any forced intra MBs gives the best quality because of the better

TABLE I
Average absolute value of motion vectors for the tested sequences.

Test sequence	*Hall*	*Paris*	*Stefan*	*Soccer*
Avg. values of MV	2.11	2.52	5.55	8.11

TABLE II
Video quality in dB for different sequences and different loss rates.

Loss rate (%)		0	2	4	6	8	10
Hall	*no-I*	39.1	31.8	28.7	27.2	26.3	25.4
	cyc-I-line	38.5	37.3	36.3	35.4	34.6	33.9
	22rand-I-MBs	38.2	36.9	35.8	35.0	34.1	33.5
	I-frame@18	38.4	35.7	33.6	32.0	30.7	29.4
Stefan	*no-I*	30.0	23.0	20.7	19.2	18.4	17.6
	cyc-I-line	29.2	26.7	25.0	23.5	22.4	21.5
	22rand-I-MBs	28.9	26.0	24.1	22.8	21.8	21.0
	I-frame@18	29.2	26.6	24.7	23.3	22.2	21.3

compression of inter-coded MBs as compared to that of the extra forced intra-coded MBs in the other streams. However, as the data drop rate increases, the *no-I* plot exhibits a steep decrease in quality. From this arises the importance of forced intra-coded MBs.

It can be seen that the *cyc-I-line* always outperforms the *22rand-I-MBs* intra-refresh scheme because of the aforementioned coding overhead of the scattered intra-coded MBs when CIP is enabled. On the other hand, using *cyc-I-line* is considerably better than using *I-frame@18* for the *Paris* sequence. Nonetheless, for the more active *Soccer* sequence, *I-frame@18* outperforms *cyc-I-line*. This is because motion (either object or camera motion) can disrupt the cleansing effect of the cyclic MB line.

Table II shows test results for the other test sequences. Overall, these results show that for active sequences, periodic I-frames are preferable, while using cyclic intra-coded line can give a considerable quality gain for less-active sequences.

IV. Conclusion

If less-active sequences can dispense with periodic I-frames, the periodic delay introduced when buffering these large-sized frames is also eliminated. This has implications for choice of video content when streaming to smartphones. The next research step is to provide adaptive content-dependent intra-refresh mode selection in an implementation that tests for motion activity.

References

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