Title

Source and channel coding trade-offs for a pulsed quality video encoder

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Source and channel coding trade-offs for a pulsed quality video encoder

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***Abstract*— Dual reference frame video coding uses one short-term and one long-term reference frame for motion compensation. Previous work examined uneven allocation of bits to the long-term reference frames. In this work, we examine uneven allocation of error protection to the long-term reference frames. We use a steepest descent algorithm to allocate source coding bits and channel coding bits to the long-term reference frames and to the other frames. The steepest descent algorithm provides about 2dB improvement in PSNR compared to equal error protection and to heuristic assignment of unequal protection for the long-term references.**

I. Introduction

Multiple reference frame motion compensation was studied in [1], [2], [3], [4]; it was shown that PSNR decreases with the increase in the number of frames, with a linear increase in complexity. In dual reference frame video encoding, only two frames are used for motion prediction: the short-term reference (STR) frame (usually the immediate past frame) and the long-term reference (LTR) frame (a frame in the more distant past). In [5], we showed that assigning different qualities to the LTR and STR frames improves average PSNR for the overall video sequence. The LTR frames are periodically updated and given extra bits (pulsed quality), at the expense of the other frames, such that the overall bit rate is constant [5]. Here, we explore the use of unequal error protection for the LTR and STR frames. We present a steepest descent algorithm for allocating source and channel coding bits to frames.

II. Coding rate assignment

We modified an MPEG-4 encoder for dual frame coding, with LTR frame update every 20 frames. The network has a 20% packet loss rate, and the encoded bitstream is packetized in equal sized packets of 800 bits. Error protection is done through Reed Solomon block codes. Inter/Intra coding mode selection of macroblocks is done by the extended ROPE algorithm [6], [7]. Using the News and Carphone test sequences, we investigate both equal error protection to all frames, as well as extra error protection for the LTR frame compared to the other frames.

For unequal assignment, we use both a heuristic approach as well as a steepest descent algorithm similar to [8] to allocate source and channel coding bits to frames. Since this algorithm is computationally intensive, it is more appropriate for offline encoding rather than real-time transmission. We applied the algorithm to groups of 20 frames. The first frame in the group is the LTR frame for the group; the remaining frames are used only as short-term references. The algorithm begins with no error protection assigned to any frame, and with the coarsest possible quantization used for each frame. The algorithm then iteratively computes the distortion-rate slope as in [8], where we consider the effect on rate and distortion of improving the quantization parameter from its current value to the next stepwise refined value for each of the 20 frames.

In an extension to [8], we also compute the distortion-rate slope for assignment of

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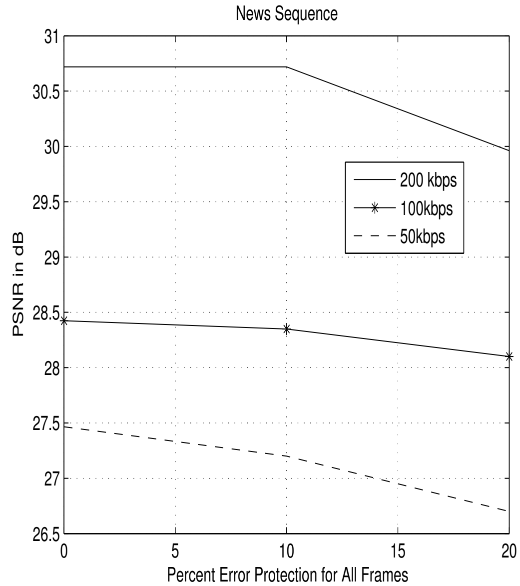
error protection to the group of frames without changing the quantization parameters. We consider two assignments: error protection for the LTR frame only, and equal error protection for all frames. We obtain the steepest descent slope over the error protection and quantization parameter space. The error protection values are chosen from the discrete set containing {0, 10, 20, 30} percent of additional redundancy. The recursion proceeds until the desired bit rate is reached.

III. Results

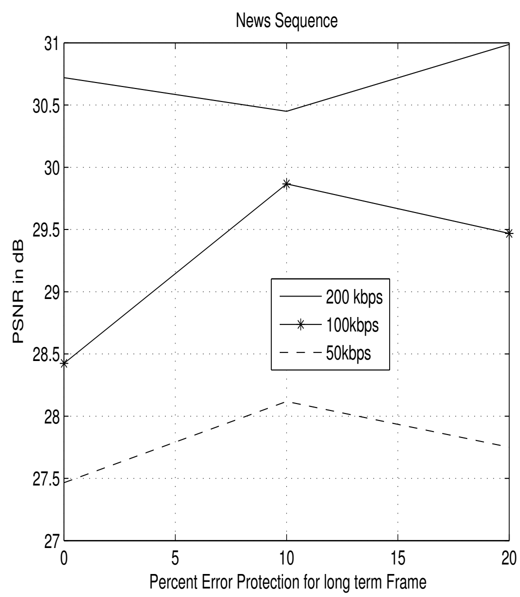
Figures 1 and 2 show simulation results for heuristically assigning error protection for the News and Carphone sequences. In all figures, each plotted point is averaged over 5 random realizations of the channel. The top graphs show results for equal protection to all frames; the bottom graphs show results when assigning protection just to the LTR frame. We show results for three different bit rates (50, 100, and 200 kbps). For each curve, we hold the total bit rate (source coding plus channel coding) constant.

Comparing the top and bottom graphs for each figure, the results show that assigning error protection for the LTR frames is better than assigning equal error protection for all frames. For the Carphone sequence, for example, results in Figure 2b show that error protection of 20% for the LTR frame improves the PSNR of the sequence by 2 dB compared to using no error protection at all. However, assigning equal protection for all frames, as shown in Figure 2a, degrades the PSNR, as too many bits are allocated to the channel coding at the expense of source coding.

Providing equal error protection for all frames uses a significant fraction of bits for channel coding. Since the LTR frame is only a single frame (although it takes more bits than a typical frame, since it is high quality), the cost to provide error protection for it alone is much less. Furthermore, this error protection is more valuable since the LTR frame is available to be referenced by all the remaining frames in the group. The modified ROPE algorithm which makes inter/intra coding mode decisions and selects which frame to use for motion compensation is biased in favor of choosing the LTR, because it has both

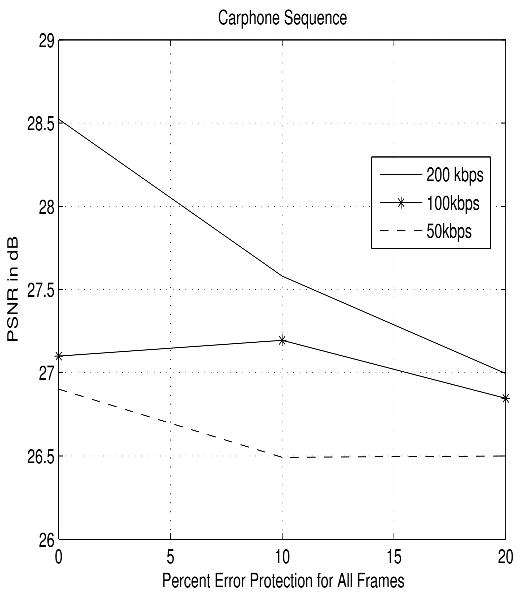


(a) PSNR versus error protection

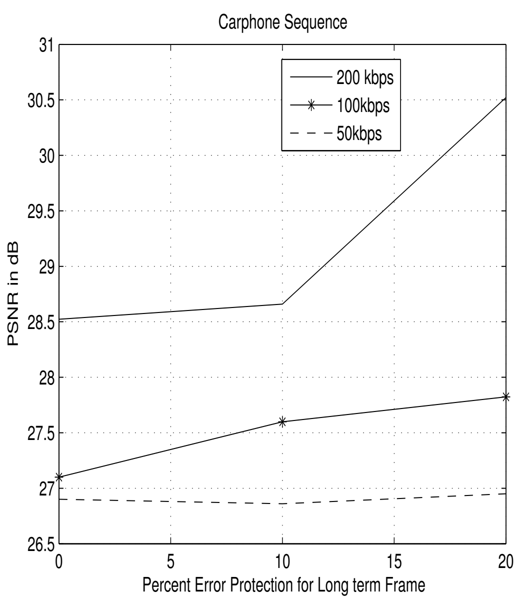


(b) PSNR versus error protection

Fig. 1. News Sequence

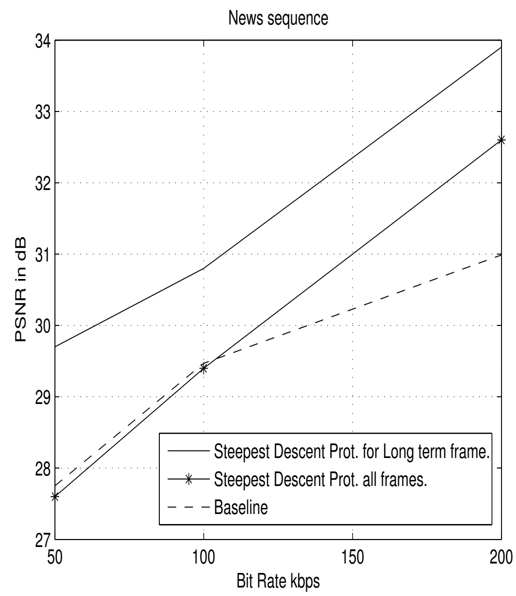


(a) PSNR versus error protection

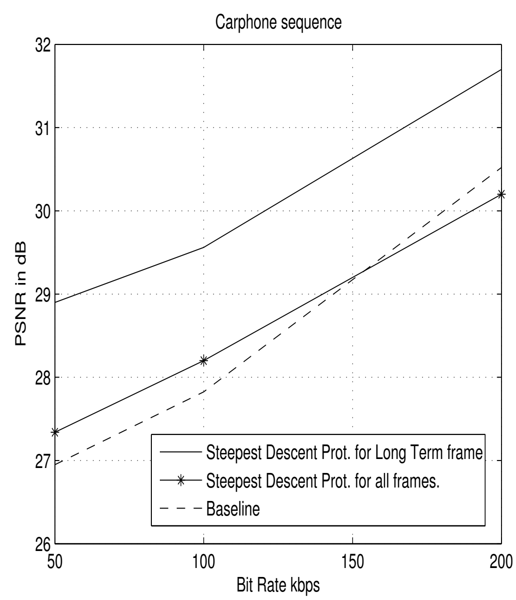


(b) PSNR versus error protection

Fig. 2. Carphone Sequence



(a) News Sequence



(b) Carphone Sequence

Fig. 3. Steepest Descent Plots

higher quality and higher protection.

Figure 3 shows the results of using the extended steepest descent algorithm to assign source coding and channel code rates as a function of channel bitrate for both the News and Carphone sequences. We show the results of three algorithms: using steepest descent to protect the LTR frame, using steepest descent for equal protection across all frames, and heuristically allocating 20% error protection for the LTR as a baseline (the results from Figures 1b and 2b at 20% protection).

The results show that the extended steepest descent algorithm substantially improves upon the best heuristic results. Steepest descent for the LTR frame provides up to 2 dB improvement over the baseline. Further, once again we see that protecting just the LTR frame provides more benefit than protecting all frames equally. Steepest descent for protecting all frames shows little benefit, and sometimes decreased PSNR, compared to the baseline. The results show that the gains in PSNR are greater when we use the steepest descent with error protection assigned only for the LTR frame compared to equal error protection.

IV. Conclusion

We analyzed the performance of the pulsed quality dual frame video encoder over a lossy network channel with packet loss ratio of 20%. We showed that protecting the long-term reference frame improves the quality (PSNR) of the video sequence. We examined the tradeoff between assigning extra protection for the LTR frame and the source coding bits for all frames, and showed that protecting just the LTR frame provides more benefit for low to medium bitrates. We further simulated the performance of the extended steepest descent algorithm, and found that it can provide substantial gains of 2 dB compared to heuristic error protection for the LTR frame.

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