FINE GRAIN SCALABILITY OF BITRATE USING AVC/H.264 BITSTREAM TRUNCATION

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ABSTRACT

Firstly the paper reports experimental results proving that Cascaded Pixel Domain Transcoder (CPDT) is extremely inefficient when used for AVC/H.264 bitstream transcoding aimed at bitrate reduction not exceeding 30% of primary bitrate. In the paper, proposed is a transcoder that exploits structured truncation of bitsream and an algorithm for such truncation is described. The experimental results are described that show that the proposed transcoder provides bitrate reduction with very small or negligible loss of quality for bitrate reductions not exceeding about 30%. The transcoder complexity is much smaller than that of CPDT.

***Index Terms*—** Transcoding, scalability, AVC, H.264, bitstream reduction

1. INTRODUCTION

Research on video transcoding algorithms and techniques is of great interest because of its significance for universal multimedia access [1-3]. In particular, attention is being gained by transcoding scenarios that involve advanced video coding techniques like MPEG-4 AVC/H.264 [4]. Such transcoding scenarios include:

- homogeneous transcoding where both input and output bitstreams are compliant with AVC/H.264 standard,
- heterogeneous transcoding where input and output bitstreams are compliant with different video coding standards.

Most of references deal with the latter scenario, e.g. with transcoding of MPEG-2 bitstreams into AVC/H.264 bitstreams. However, this paper deals with the first scenario.

Here, we consider transcoders that transform an AVC/H.264 bitstream into another AVC/H.264 bitstream with reduced bitrate. Actually, very few papers considered homogeneous transcoding of AVC/H.264 bitstreams [5,9]. Hitherto, such transcoding has been described mostly in the context of transform coefficient requantization [5-9].

The most straightforward transcoder configuration consists of full decoder followed by an encoder. It is called Cascaded Pixel Domain Transcoder (CPDT) (see Fig. 1). Unfortunately implementations of this transcoder are very computationally expensive and numerous research papers have described various attempts to reduce transcoder complexity. Unfortunately most papers do not care about inevitably reduced quality of video related to the output of Cascaded Pixel Domain Transcoder (CPDT). Here, we report experimental results on video quality loss due to transcoding of AVC/H.264 bitstreams in CPDT. The results are similar as those reported for such transcoding of MPEG-2 bitstreams [6,7].

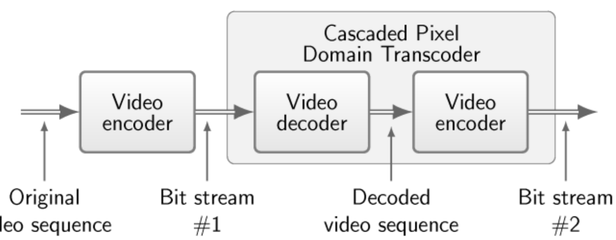

Fig. 1. Cascaded Pixel Domain Transcoder (CPDT).

In the paper, we prove the video quality loss may be substantially reduced by avoiding of decoding and encoding. Here, we propose an algorithm for structured truncation of AVC/H.264 bitstream that reduces numbers of bits allocated for transform coefficients. In that way also the transcoder complexity is substantially reduced.

Using the proposed algorithm of structured truncation of AVC/H.264 bitstreams, we are able to reduce bitrate of an AVC/H.264 bitstream by a grainless portion without significant loss of video quality unless this portion does not exceed some limit. Such a feature is called fine grain scalability and numerous research attempts have been aimed at its efficent implementations. As these attempts proved limited success, fine granularity scalability has not been included into scalable extension of AVC/H.264 standard [4].

Here, for the proposed algorithm of structured truncation of AVC/H.264 bitstreams, we report experimental results proving that fine grain scalability of bitrate is obtainable in a straighforward way using standard nonscalable bitstreams and with usually quite small loss of quality. The loss of quality is much lower than that related to application of CPDT unless the bitrate is greater than some limit related to the portion of bitstream representing transform coefficients.

2. ERRORS GENERATED IN CASCADED PIXEL DOMAIN TRANSCODER

For Cascaded Pixel Domain Transcoder (CPDT), the rate-distortion curve for the output video lies much below that for the first enccoding (see Fig. 2). Even decoding and encoding with the same bitrate is inevitably related to a loss of quality.

For given bitrate we may measure quality loss $\Delta_{quality}$ due to transcoding (see Fig. 2). Alternatively, for given quality we may measure bitrate increase as $\Delta_{bitrate}$ due to transcoding.

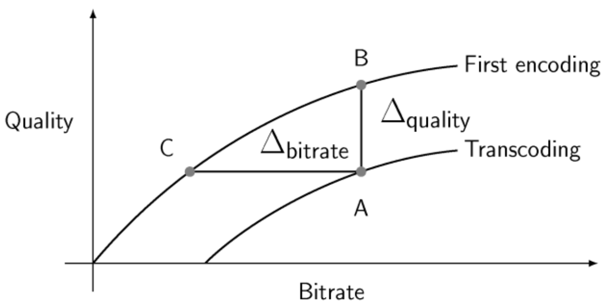

Fig. 2. Quality and bitrate loss due to transcoding.

In order to measure systematically the quality loss due to transcoding in CPDT, experiments have been performed using AVC/H.264 reference software (JM ver. 13.2) [11]. At first, original sequences were encoded with a set of different values of primary quantization scale index QP_F. The index was set the same for I and P images while B images had QP_F increased by 2. Then the obtained bitstreams have been transcoded using CPDT. At the output of CPDT, the sequences have been encoded with various values of quantization scale index $QP_T \geq QP_F$. For a given bitrate, the loss of quality $\Delta_{quality}$ has been measured as the luminance PSNR difference Δ_{PSNRY} between interpolated PSNR-bitrate curves.

The experiments have been done for 4cif, 30Hz sequences. For all experiments CABAC encoders and decoders have been used. Results for "City" sequence are presented in Figs. 3 for various values of primary quantization scale index QP_F. The results for 4 test video sequences ("City", "Crew", "Harbour", "Soccer") with 117 frames and I-B-B-B-P-B-B-B-P-B-B-B-P-B-B-B GOP are summarized in Figs. 4 and 5.

The conclusions are the following. The loss of quality due to CPDT is usually slightly smaller when the in-loop deblocking filter is switched on (compare Fig. 4 against Fig. 5). The maximum loss of quality is related to moderate reduction of bitrate of about 20-30%. For higher bitrate reductions exceeding 50%, the loss of quality due to CPDT is smaller and vanishes to almost zero as bitrate reduction exceeds 80%. Therefore CPDT is extremely inefficient for moderate bitrate reductions not exceeding 30% similarly as for MPEG-2 streams that have been considered in [6,7].

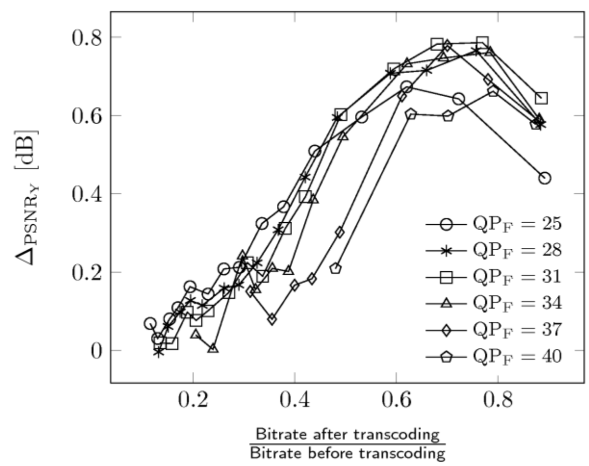

Fig. 3. Quality loss due to CPDT with in-loop deblocking filter switched always ON (test sequence "City").

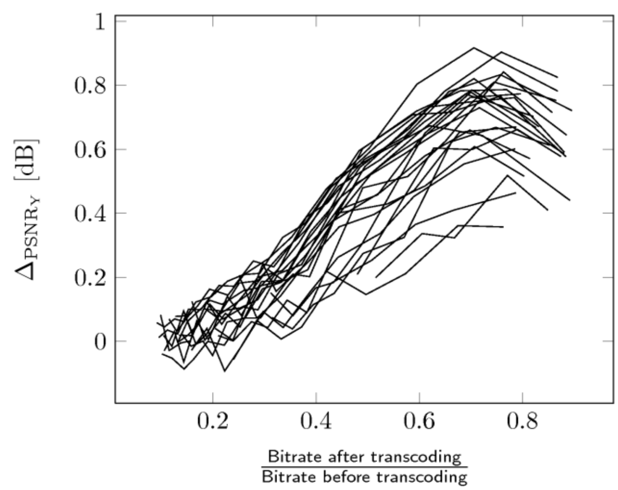

Fig. 4. Quality loss due to CPDT with in-loop deblocking filter switched always on (4 test sequences and various QP_T).

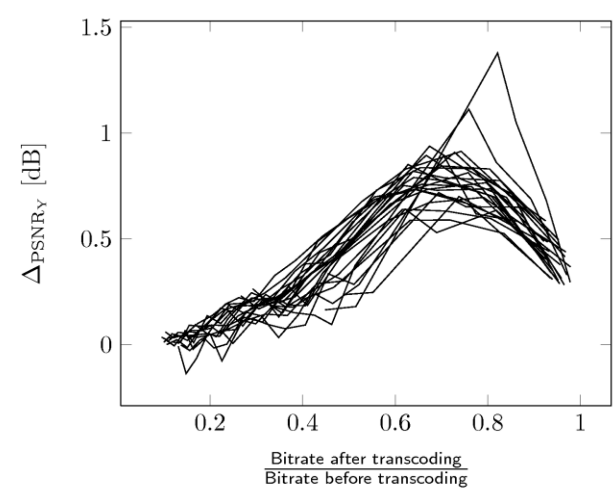

Fig. 5. Quality loss due to CPDT with in-loop deblocking filter switched always OFF (4 test sequences and various QP_T).

3. BIT RATE REDUCTION VIA BITSTREAM TRUNCATION

Instead of use of CPDT, we propose to use a much simpler transcoder that exploits removal of transform coefficients in order to reduce bitrate (see Fig. 6). Except of the block of selective removal and modification of transform coefficients, such a transcoder consists of bitstream parser with CABAC (or VLC/CAVLC) decoder as well as of CABAC (or VLC/CAVLC) encoder and bitstream formatter.

In AVC/H.264 bitstreams, for moderate bitrates (1.5-2.0 Mbps, $QP_F \approx$ 28-30) transform coefficients correspond to about 30-35% of bitrate. For higher bitrates this percentage even increases (Fig. 7). For moderate bitrates, 60-90% of those coefficients exhibit absolute value of 1.

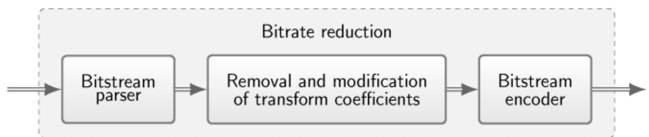

Fig. 6. Bitrate reduction via bitstream truncation.

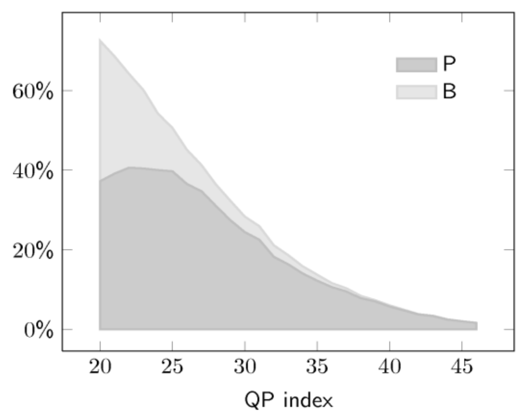

Fig. 7. Portion of bitrate that corresponds to transform coefficients in P and B slices ("City"sequence).

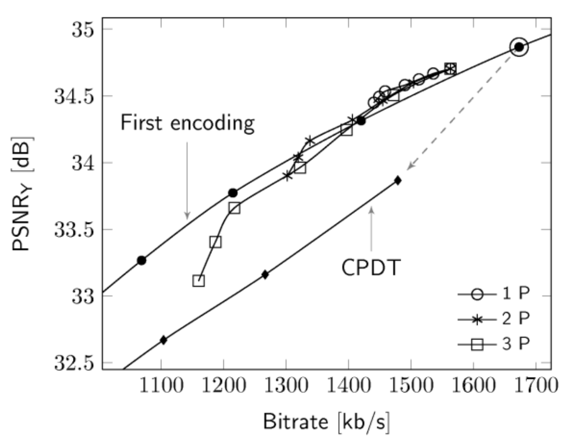

Fig. 8. Quality loss due to bitstream truncation (removal and modification of coefficents in B images and in 1, 2 or 3 P images) for test sequence "City".

Therefore bitrate reduction not exceeding 30% may be obtained via removal of coefficients except the most important ones. Firstly removed and modified are smallest coefficients in B images as these operations do not result in drift. The respective compression performance is virtually the same as for the first encoding (Fig. 8). Removal of small coefficients in P images introduces drift into reconstructed video therefore this operation must be done more carefully and starting from the last P image in Group of Pictures (GOP).

4. PROPOSED ALGORITHM FOR BITSTREAM TRUNCATION

The observations from previous section as well as many experimental results yield the following algorithm of bitstream truncation.

Bitstream truncation algorithm:

1. Eliminate coefficients with absolute value equal to 1 in B slices (for better subjective quality starting from macroblocks located more peripherally in pictures).
2. Divide all coefficients' values in B slices by 2 and put into bitstream QP index value increased by 6 for the respective macroblocks.
3. Repeat steps 1 and 2 for P slices, starting from the last P in GOP and continuing towards the beginning of GOP.
4. Eliminate half of coefficients with absolute value equal to 1 in B slices.
5. Eliminate half of coefficients with absolute value equal to 1 in P slices.
6. Eliminate rest of coefficients with absolute value equal to 1 in B slices.
7. Eliminate rest of coefficients with absolute value equal to 1 in P slices.

5. COMPRESSION PERFORMANCE OF TRANSCODING VIA BITSREAM TRUNCATION

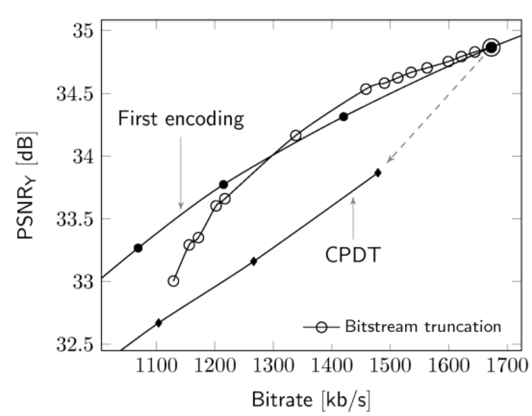

Fig. 9. Rate-distortion curve for the proposed bitstream truncation transcoder compared to the first (primary) encoding and CPDT. (sequence "City").

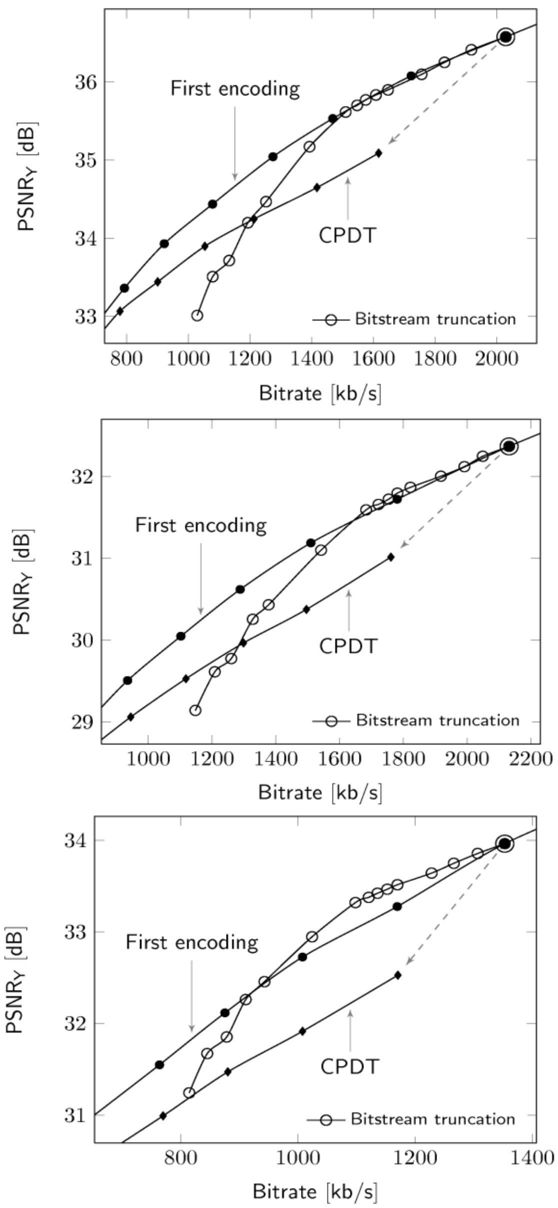

Fig. 10. Rate-distortion curve for the proposed bitstream truncation transcoder compared to the first (primary) encoding and CPDT. (sequences "Crew", "Harbour" and "Soccer", respectively).

Table 1. Quality gain of bitstream truncation transcoder versus CPDT calculated for test sequences and exemplary bitrate reductions as well as various values of QP_F in the input bitstream.

QP_F	Quality gain [dB]			
	City 15% reduction	Crew 25% reduction	Harbour 25% reduction	Soccer 25% reduction
25	0.914	0.819	0.986	0.910
28	1.050	0.922	1.021	1.017
31	1.034	0.945	0.928	0.965
34	0.592	0.778	0.694	0.738
37	---	0.728	-0.249	0.508

In order to test the compression efficiency for the proposed transcoder, the experiments have been performed under the same conditions as described in Section 2. The results (Figs. 9 and 10, Table 1) show that the loss of quality is much smaller for the proposed transcoder as compared to CPDT until bitrate reduction does not exceed about 30%. For bitrate reduction not exceeding about 15% the compression performance (rate-distortion performance) is virtually the same as for fist AVC/H.264 encoding.

5. CONCLUSIONS

In the paper, proposed is a transcoder that exploits structured truncation of bitstream and an algorithm for such truncation is described. The experimental results are described that show that the proposed transcoder provides bitrate reduction with very small or negligible loss of quality for bitrate reductions not exceeding about 30%, i.e. for the bitrate reduction range where CPDT is extremely inefficient. The transcoder complexity is much smaller than that of CPDT.

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6. REFERENCES

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