Video quality in AVC homogenous transcoding

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***Abstract*— In this paper the results obtained for homogenous Cascaded Pixel Domain Transcoder of AVC bitstreams are reported in order to show the expected transcoding efficiency gain/loss. A wide set of test video sequences has been used in experiments and in total 19200 bitstreams have been encoded and examined. It has been proved that there is a universal dependency between the quality, defined as ΔPSNR and bitstream reduction. ΔPSNR is described as the difference between quality of the transcoded material and the original material that could potentially be encoded at the same bitrate as the transcoded one.**

***Keywords* - video; compression; video coding; transcoding; AVC; H.264; MPEG; CPDT**

I. INTRODUCTION

The Advanced Video Coding (AVC) standard [1] has been developed by Joint Video Team (JVT), the joined body of ISO/IEC MPEG (Moving Picture Experts Group) and ITU-T VCEG (Video Coding Experts Group). Therefore the standard and the corresponding video coding technology are called as MPEG-4 AVC or H.264. The AVC technology has been designed as a successor of MPEG-2 in TV broadcast and entertainment system, and a successor of MPEG-4 Part 2 and H.263 in teleconference and real-time systems.

The AVC is block-based hybrid video coding standard [2,3] exploiting intra frame block-based directional prediction and inter frame motion compensated prediction. The prediction residual is transformed by using integer 4x4 (also 8x8 in High profile) separable DCT-based transform. The transform coefficients are quantized. The quantized coefficients are entropy encoded with Context-Adaptive Variable-Length Coding (CAVLC) or Context-Adaptive Binary Arithmetic Coding (CABAC) encoder. More details about AVC can be found in [2,3].

Bitrate of the bitstream is controlled by quantization step size of the transform coefficients. Quantization introduces information loss and is responsible for decoded image quality degradation. The quantization is controlled by Quantization Parameter (QP). QP value ranges from 0 to 51, where: QP=0 means the best decoded image quality but highest required bitrate; QP=51 means the lowest image quality and requires the lowest bitrate. Commonly used QP values lies in the range 25 ÷ 35.

AVC has been widely adopted to many modern broadcasting systems (e.g. DVB-T, DVB-S2, DVB-H), digital video distribution systems (e.g. Blu-ray), network streaming systems, consumer digital cameras and even in video surveillance systems. Therefore, AVC is recognized as one of the most popular and widely adopted video compression standard.

Every time new video compression standard is deployed onto the market, people dealing with transcoding face a new research area to explore. The same happened when AVC started to replace MPEG-2 many years ago in many applications. There are many publications dealing with transcoding from and to AVC [4-8]. In literature one can easily find heterogeneous, as well as homogenous transcoders where AVC is investigated both as a source or a target standard. The most commonly considered issue is a bitstream reduction with small computational overhead. However, we did not find any complex analysis of homogenous Cascaded Pixel Domain Transcoder (CPDT). CPDT is the most straightforward, yet very computationally complex approach [9]. However, since the encoder uses uncompressed video sequence and is not restricted, achieved results are probably the best to be achieved during transcoding. Therefore, it would be very interesting to know what can we gain or lose in terms of video quality and bitrate when AVC compliant bitstream will be fully decoded and again encoded.

II. PROBLEM DEFINITION

Let us consider the following example (Figure 1): the given sequence encoded at particular bitrate (BitrateStartingPoint) is transcoded with CPDT in order to reduce necessary bitrate (BitrateTranscoded). The question arises what is the quality of transcoded material compared to the quality of the original material that could be potentially encoded for the first time at the same bitrate (ΔPSNR)? Finding an answer to this question would allow to asses additional quality degradation caused directly by image transcoding.

Every time the video material is decoded and encoded again, there is no possibility to avoid re-quantization of previously compressed (quantized) signal. Obviously the re-quantization process causes inevitable and irreversible quality loss.

Additionally, we would like to answer the following question. How to change bitrate during transcoding in order to get minimal quality loss compared to the quality of the original material that could be potentially encoded at the same bitrate? It is very important, especially due to its significance for universal multimedia access [9-11] were signal is transmitted through heterogeneous networks.

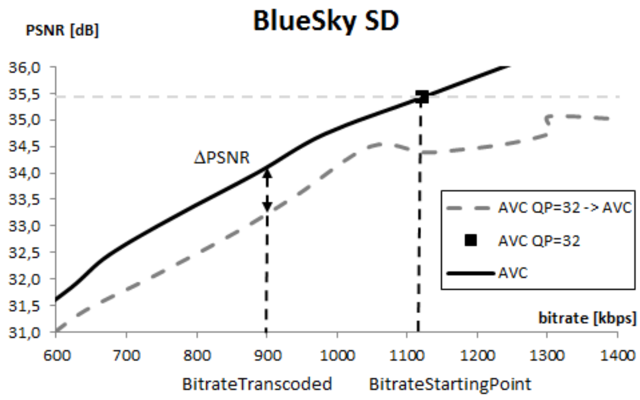

Figure 1. Definition of quality difference (ΔPSNR) calculations for CPDT from AVC to AVC.

III. METHODOLOGY

To answer the above mentioned question the following experiments were performed. A number of widely recognized video test sequences have been encoded with AVC video encoder (JM 18.4) with QP values from the range 10-50. Thus we get 40 bitstreams per sequence that differ in quality (PSNR of luma) and required bitrate. The AVC encoder used typical configuration dedicated for high quality TV services (see Table 1). Next, each of those 40 bitstreams have been decoded and each again encoded with QP values from the range 10-50 simulating bitrate change. For all such transcoded sequences we have collected necessary bitrate and the corresponding quality of the decoded material in terms of luminance PSNR metric (always in relation to the original sequence).

TABLE I. ESSENTIAL CONFIGURATION PARAMETERS USED.

Parameter	Value
Profile	Main
GOP	IBBPBBPBBPBBPBB
Hierarchical GOP	No
No. of ref. frames	5
RDO	On
Search range for ME	±32
Entropy coding	CABAC

Having these results we are able to analyse how quality and bitrate change due to transcoding.

IV. EXPERIMENTAL MATERIAL

Experiments were conducted on a wide range of video sequences recommended by MPEG Committee experts of the International Organization for Standardization as a video test material for video compression techniques development and evaluation. The used video sequences test set covers wide range of content characteristics, including significantly different spatial and temporal activity. In total we used 12 SD (704x576) sequences: *Bluesky*, *City*, *Crew*, *Harbour*, *Ice*, *PedestrianArea*, *Riverbed*, *Rushhour*, *Soccer*, *Station2*, *Sunflower* and *Tractor* (see Figure 2).

Figure 2. Video Test Sequences used in the experiments in order from top-left: *Tractor*, *Sunflower*, *Station2*, *Soccer*, *Rushhour*, *Riverbed*, *PedestrianArea*, *Ice*, *Harbour*, *Crew*, *City*, *Bluesky*.

V. RESULTS

For each of the 12 sequences used in experiments sequences, 40 bitstreams were produced and for each of those bitstream, 40 transcoded bitstream were produced. In total we get 12*40*40 = 19 200 bitstreams. Such a large number of cases different in bitrate reduction and quality degradation allows a generic conclusion about CPDT transcoding.

Figure 3 shows exemplary results for BlueSky sequence. The black line is a rate-distortion (R-D) curve for AVC-encoded video. Black square points represent exemplary starting points used for transcoding (i.e. AVC coded material at different QP values). Additionally, horizontal light-grey dashed lines show quality (PSNR) of each starting point. Obviously, none of AVC-transcoded material created based on each starting point can exceed the starting point quality. Based on those starting points, grey lines were created which represent AVC transcoded material, one line per each starting point.

Analysing the results in form presented on Figure 3 can lead to misleading conclusions. In order to find the answer to the question about the influence of bitrate reduction on the quality, a different type of plot is required. On Figure 4 the same data of four transcoded bitstreams has been presented. ΔPSNR is the difference between quality of the transcoded material and the original material that could be potentially encoded at the same bitrate (see Figure 1). The *BitrateStartingPoint* and *BitrateTranscoded* are the bitrates of the sequence before and after cascaded pixel domain transcoding respectively.

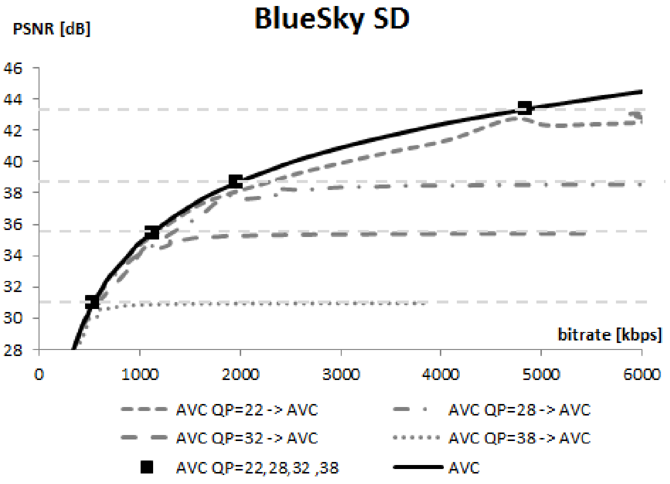

Figure 3. Exemplary results for Bluesky SD sequence.

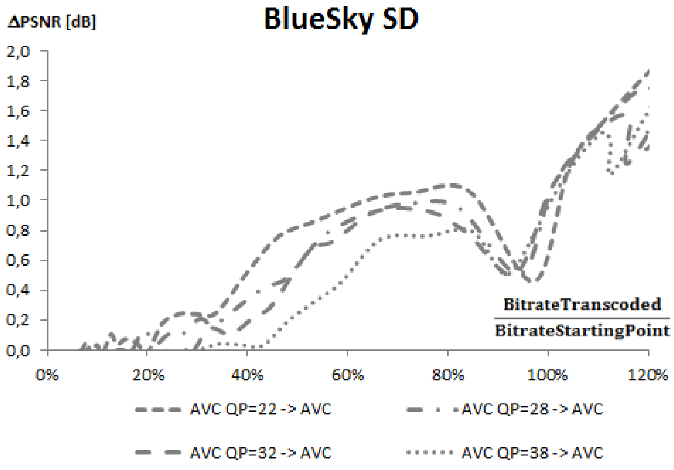

Figure 4. ΔPSNR with respect to bitstream reduction after transcoding for an exemplary sequence and QP values used for encoding starting points.

Results for all sequences at all bitrates are shown on Figure 5. Black line shows average quality difference (ΔPSNR) versus bitrate reduction (during transcoding).

Analysing the average curve (see Figure 6) one can see that transcoding at the same bitrate (100%) cause on average ΔPSNR=0.896dB quality degradation. It is not the maximum quality degradation. Of course transcoding with the increased bitrate leads to the increase of ΔPSNR, because quality of the transcoded material will not be better than quality of the starting point. In case of transcoding with lower bitrate, the quality degradation drops at 96% of the starting point bitrate and has a local minimum of 0.764dB loss. Next, it increases and reaches local maximum (0.94dB) at about 80% of the starting bitrate. Then ΔPSNR decreases again passing the point with 60% bitrate reduction with the same quality loss as at 96% (0.764dB).

We have also analysed whether the transcoding R-D curve has universal character or not (whether it can be average or not). The additional ΔPSNR curves has been calculated. From that we have averaged the value for each QP for all sequences (Figure 7) and for each sequence for all QPs (Figure 8).

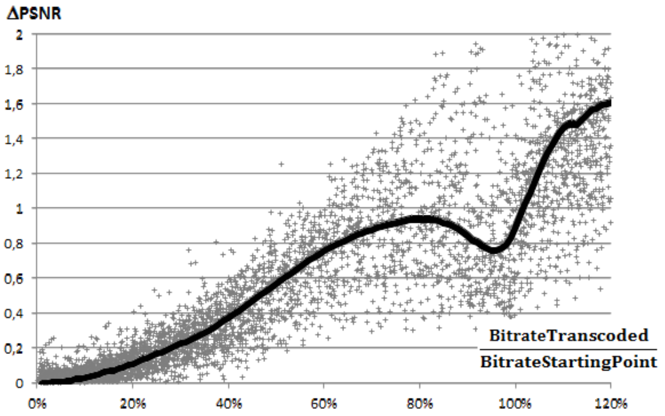

Figure 5. ΔPSNR with respect to bitstream reduction after transcoding for all test sequences.

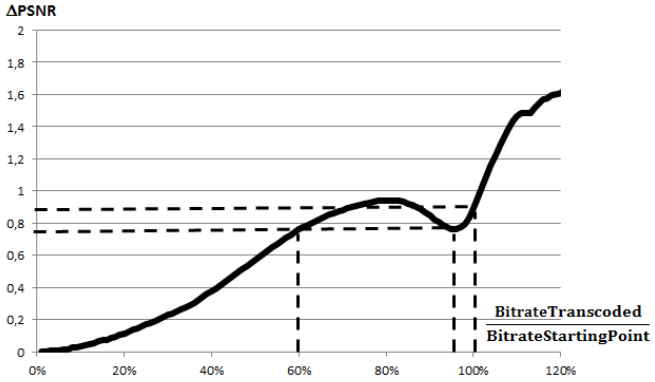

Figure 6. Average over all bitrates and all test video sequences ΔPSNR with respect to bitstream reduction after transcoding.

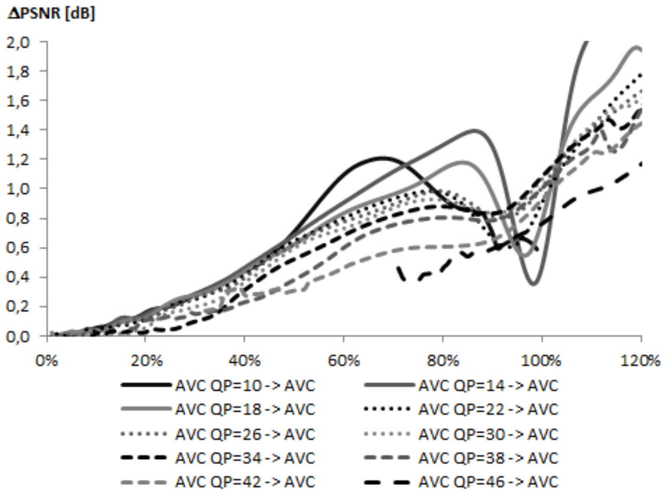

Figure 7. ΔPSNR averaged over all test sequences for selected QP values used for encoding starting points.

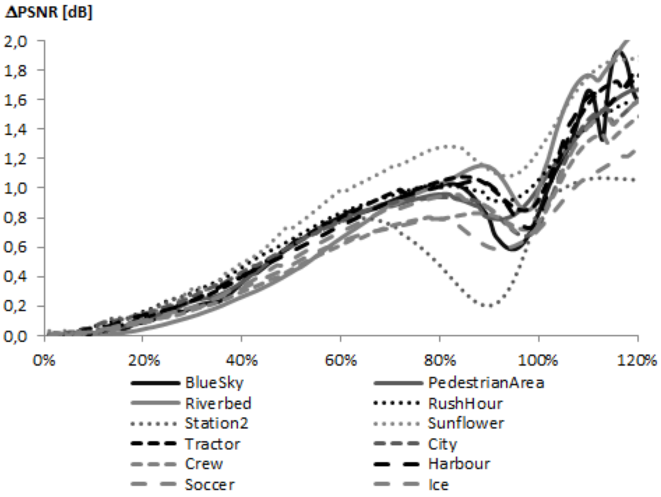

Figure 8. ΔPSNR averaged over all QP values used for encoding starting points for all test sequences.

VI. CONCLUSIONS

In the paper we have analysed quality degradation of the transcoded material compared to the quality of the original material that could be potentially encoded at the same bitrate as the transcoded one. Experiments show that maximum quality loss is when transcoding the material at 81% of the input bitrate (ΔPSNR=0.94dB). On the other hand local minimum of quality loss is at 96% of the starting point bitrate (0.764dB). The same quality difference can be observed at 60% of the starting bitrate. The characteristic of the results is probably determined by the relationship between original and second quantization (re-quantization). It will be subject of the further study. Transcoding with no bitrate change (100%) causes 0.764dB quality loss. Presented results allow to asses additional quality degradation caused directly by image transcoding.

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