Video transrating in AVC to HEVC transcoding

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Abstract - **HEVC (MPEG-H Part 2 and H.265) is a new coding technology which is expected to be deployed on the market along with new video services in the near future. HEVC is a successor of currently widely used AVC (MPEG-4 Part 10 and H.264). In this paper, the quality coding gains obtained for the Cascaded Pixel Domain Transcoder of AVC-coded material to HEVC standard are reported. Extensive experiments showed that transcoding with bitrate reduction allows the achievement of better rate-distortion performance than by compressing an original video sequence with the use of AVC at the same (reduced) bitrate.**

Keywords - **AVC; CPDT; HEVC; transcoding; transrating**

I. INTRODUCTION

Research on video transcoding techniques and algorithms is a very active topic, especially because of its significance for heterogeneous communication networks and a variety of user-end-systems [1-3]. Every time when new coding technology is supposed to be deployed on market, those research become more intensive. Currently, a new video coding technology, HEVC - High Efficiency Video Coding (MPEG-H Part 2, H.265) [4], has been finalized by ISO/IEC MPEG and ITU-T VCEG. HEVC offers up to 50% bitrate reduction in comparison to the commonly used AVC (MPEG-4 Part 10 and H.264) [5], while preserving the same subjective video quality [6].

Generally HEVC utilizes the same compression scheme as AVC - hybrid video coding [7]. Hybrid video coding consists of: image division into non-overlapping blocks, samples prediction with motion compensation, transformation and entropy coding. The HEVC compression efficiency increase over AVC has been achieved by improvements in most of the existing coding tools (utilized in AVC) and by introducing new tools [4]. The most important improvements are focused on:

- flexible structure of a coding block size (coding units - CU, prediction units - PU and transform units - TU) with CUs organized in a quad-tree structure,

- variety of prediction unit sizes (4x4 to 64x64) with square and rectangular PU shapes,

- variety transform unit sizes (4x4 to 32x32) with DST and "transform skip" available for smallest TUs (as addition to DCT),

- intra prediction with increased number of available directions (35 from 9 in AVC) and advanced predictive coding of intra direction and intra reference smoothing,

- inter prediction, with improved 8-tap interpolation filters, reduced rounding errors and effective motion field

prediction modes (like motion vector competition and merge mode),

- coefficient coding based on improved CABAC with increased throughput and adaptations to encode bigger transform blocks.

The introduction of new coding tools includes:

- transform skip mode – allowing for passing the transform stage and encoding prediction error directly,

- sample adaptive offset (SAO) – an additional adaptive loop filter intended to reduce ringing artifacts,

- wavefronts and tiles allowing for massive parallel processing (encoding and decoding).

Due to significantly higher compression efficiency of HEVC, it is expected that new video systems (e.g. 4K video, video streaming) that exploit HEVC will be deployed in the near future. Thanks to a huge amount of legacy video material, new transcoding scenarios involving the HEVC technique will probably attract a lot of attention.

Most of the works currently being published focus on reducing the quality losses caused by transcoding or/and complexity reduction [8-14] in comparison to the so called Cascaded Pixel Domain Transcoder (CPDT) [3]. The CPDT is the most straightforward transcoder configuration that consists of a full decoder followed by an encoder. In other words we get the knowledge about how different approaches to transcoding using information about motion vectors [10,12,14], image partitioning [10,11], selected modes [11] can speedup this process and also influence the coding efficiency. However, always in relation to the CPDT. A question to be answered, what might be expected from CPDT approach? It is obvious that transcoding introduces inevitable and irreversible quality loss. However, HEVC provides more efficient data representation than AVC. Therefore, it would be very interesting to know which effect (quality loss caused by re-quantization, or more efficient data representation) is stronger.

Another aspect of great practical importance in transcoding is transrating (transcoding that leads to bitrate change) [8, 10, 13, 14, 15]. There are many situations when a smaller video bit stream is desired, for example in order to fit to communication channel or smaller file size to simply save space on a hard drive. Therefore, when the original video is unavailable (most of the cases) we can transcode our compressed video to lower bitrate. A question arises, what can be achieved in terms of coding efficiency, when during transrating we additionally change the compression standard (in our case from AVC to HEVC)?
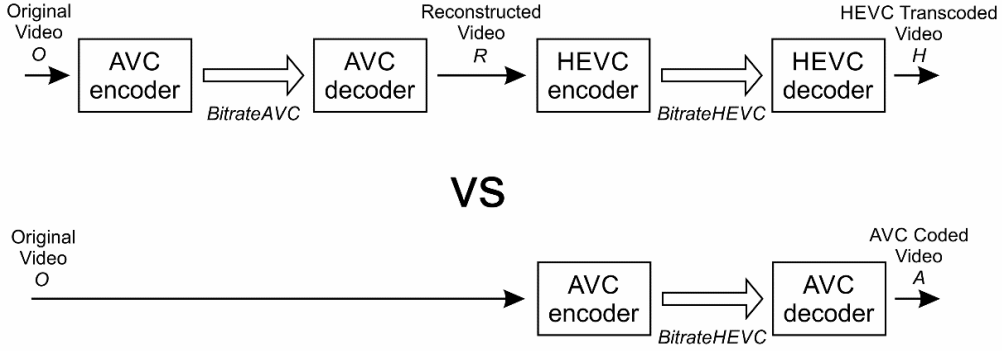
Figure 1. Methodology of the experiments and definition of the ΔPSNR.

In the paper, we will clearly show that transcoding from AVC to HEVC can bring not only zero quality losses, but surprisingly, even objective quality gains in terms of PSNR. Such conclusions are drawn from extensive experiments concerning CPDT from AVC to HEVC. The authors are not aware of any reference to CPDT rate-distortion performance, such as presented in this paper.

II. METHODOLOGY

In order to evaluate the performance of CPDT from AVC to HEVC, a number of test video sequences were encoded using AVC for a wide range of bitrates (bitrate controlled by *QP*). Then, each AVC-encoded bitstream were transcoded to HEVC, again for a wide range of bitrates (controlled by *QP* value). The bitrates were gathered before and after transcoding along with a corresponding quality of the decoded material in terms of the luminance PSNR metric (always in relation to the original uncompressed sequence). This allows a comparison of rate-distortion curves after transcoding with those obtained for AVC. Scheme of performed experiments has been shown in Fig. 1.

For the transcoded material, the PSNR difference (ΔPSNR) were calculated. The ΔPSNR is defined as the difference between the quality of the material transcoded with the use of HEVC and the quality of the original material that could potentially be encoded with the use of AVC at the same bitrate as the HEVC-transcoded one (see also Fig. 2):

$$\Delta PSNR = 10 log \frac{N \cdot 255^2}{\sum (H-O)^2} - 10 log \frac{N \cdot 255^2}{\sum (A-O)^2} \quad (1)$$

where *N* is the number of samples in the image (image size), *O*, *H* and *A* are the values of image samples of original, transcoded and encoded images respectively (see also Fig. 2).

III. EXPERIMENTS

All experiments according to presented methodology were conducted on a wide set of video sequences recommended by ISO/IEC MPEG as video test material for video compression technique evaluation during AVC development. The video sequences test set used covers a wide range of content characteristics in legacy video material. In total, we used 19

sequences: 7 – HD (1920x1080): *Bluesky, Pedestrian, Riverbed, Rushhour, Station2, Sunflower, Tractor* and 12 – SD (704x576): *Bluesky, City, Crew, Harbour, Ice, Pedestrian, Riverbed, Rushhour, Soccer, Station2, Sunflower* and *Tractor* (Fig. 3). For the production of AVC-encoded material, the H.264/AVC reference software JM 19.0 [16] with all possible *QP* values from the range 10÷50 was used. Each bitstream, after being decoded, was again encoded with an HEVC reference software version HM 16.0 [17], again with all possible *QP* values from the range 10÷50. This resulted in 12•41•41=20172 transcodings for SD sequences and 7•41•41=11767 transcodings for HD sequences. Both encoders were configured according to a sets of conditions, recommended by ISO/IEC MPEG, which are broadly used by scientific community for comparison of compression techniques (i.e. for AVC [18] and for HEVC [19]). Table I presents the essential configuration parameters used for AVC and HEVC encoders.
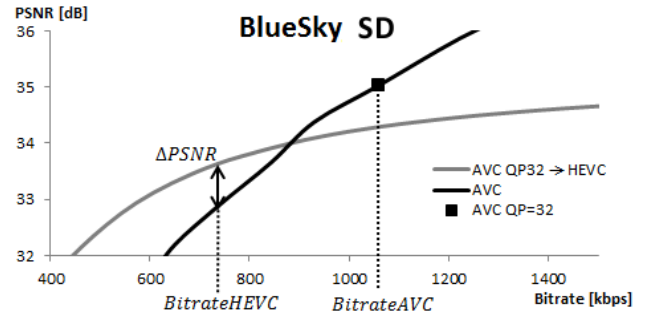

Figure 2. Example of ΔPSNR calculations for CPDT from AVC to HEVC. '*AVC QP32→HEVC*' describes the rate-distortion curve achieved for the transcoding of material encoded with the use of AVC with *QP*=32 (starting point) to HEVC.

Figure 3.   Exemplary images from video test sequences of SD resolution used in the experiments in order from top-left: *Bluesky*, *City*, *Crew*, *Harbour*, *Ice*, *PedestrianArea*, *Riverbed*, *Rushhour*, *Soccer*, *Station2*, *Sunflower*, *Tractor*.

TABLE I.   ESSENTIAL CONFIGURATION PARAMETERS USED FOR AVC AND HEVC ENCODERS.

Parameter	AVC	HEVC
Profile	Main for SD sequences/ High for HD sequences	Main for SD and HD sequences
GOP	IBBPBBP… GOP size = 16	IBBB… GOP size = 16
Hierarchical GOP	No	Yes
No. of ref. frames	5	4
Rate-Distortion Optimization	On	On
Search range for Motion Estimation	±16 for SD / ±32 for HD	±64
Entropy coding	CABAC	CABAC

IV.   RESULTS

Exemplary results for the *BlueSky* sequence (SD resolution) and *Rushhour* (HD resolution) have been shown in Fig. 4 and 5 respectively. The black line is the rate-distortion curve for AVC-encoded material. The black square points represent exemplary starting points used for transcoding (i.e., AVC-encoded material at different *QP* values). Additionally, the horizontal black dotted lines show the quality (PSNR for luminance in relation to the original sequence) of each starting point. Obviously, none of the HEVC-transcoded material created on the basis of this starting point can exceed this line in terms of quality. Based on the starting points, the grey lines were created, representing HEVC-transcoded material, one line per each starting point. For the transcoded material, the PSNR difference (*ΔPSNR*) was calculated for luminance component (Y).
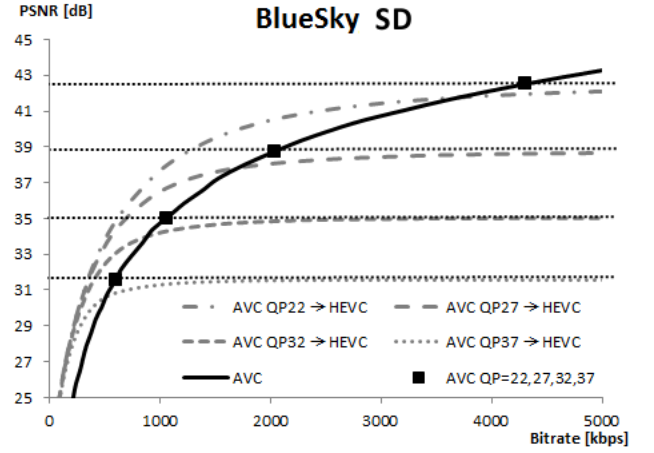

Figure 4.   Exemplary results for CPDT from AVC to HEVC for *BlueSky* SD sequence. '*AVC QP22→HEVC*' describes the rate-distortion curve achieved for the transcoding of material encoded with the use of AVC with *QP*=22 (starting point) to HEVC.
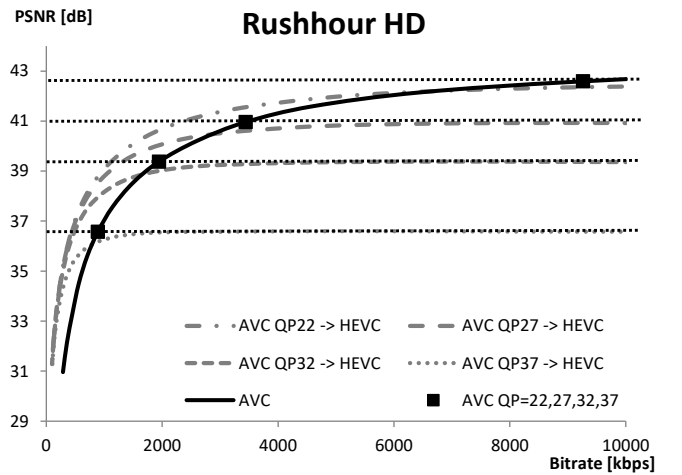

Figure 5.   Exemplary results for CPDT from AVC to HEVC for *Rushhour* HD sequence. '*AVC QP22→HEVC*' describes the rate-distortion curve achieved for the transcoding of material encoded with the use of AVC with *QP*=22 (starting point) to HEVC.

The $\Delta PSNR$ with respect to the bitrate ratio between HEVC-transcoded material (*BitrateHEVC*) and its AVC-coded starting point (*BitrateAVC*) for SD and HD sequences, have been shown in Fig. 6 and 7 respectively. Additionally, the black line shows the quality difference (*ΔPSNR*) versus bitrate reduction (caused by transcoding) averaged over all sequences.
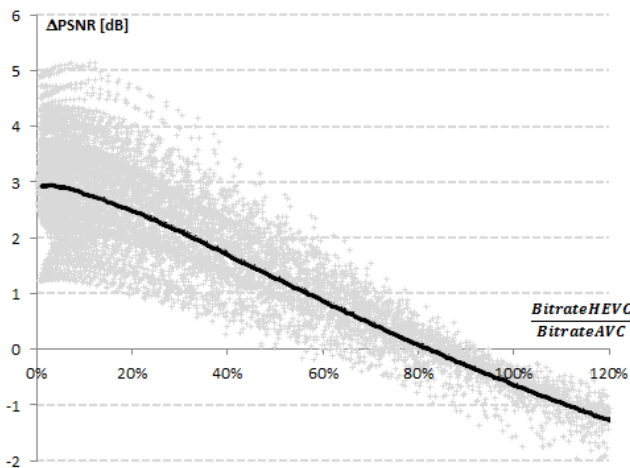
Figure 6. ΔPSNR with respect to bitstream reduction after transcoding for SD resolution sequences. The black line indicates the quality difference averaged over all SD sequences and all QP values used.
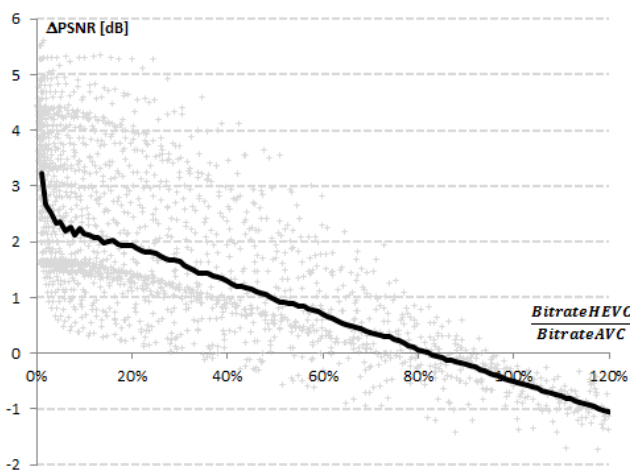

Figure 7. ΔPSNR with respect to bitstream reduction after transcoding for HD resolution sequences. The black line indicates the quality difference averaged over all HD sequences and all QP values used

V. CONCLUSIONS

Surprisingly, as shown in Figs. 6 and 7, the transcoding of AVC-encoded material to HEVC with the bitrate reduction of 20% or more gives, on average, objective quality gains with respect to AVC rate-distortion characteristics. It means that a video sequence, once transcoded to HEVC, is represented more efficiently than with the use of AVC. Therefore, despite the quality degradation caused by re-quantization (transcoding), it is possible to achieve a better rate-distortion performance compared to compressing the original video sequence with the use of AVC. Such relation was not observed for any other transcoders between previous compression techniques.

Of course, transcoding from AVC to HEVC at the same bitrate causes an average quality loss of 0.5dB for both SD and HD sequences (see Figs. 6 and 7). Therefore, transcoding with preserving the same bitrate obviously causes a reduction in signal representation efficiency.

To conclude, transcoding from AVC to HEVC along with bitrate reduction might be considered as a very promising approach in practical applications.

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