Video Quality in Multiple HEVC Encoding-Decoding Cycles

Jakub Stankowski, Tomasz Grajek, Krzysztof Wegner, Marek Domański
Chair of Multimedia Telecommunications and Microelectronics
Poznań University of Technology
ul. Polanka 3, 60-965 Poznań
e-mail: {jstankowski,tgrajek,kwegner}@multimedia.edu.pl

***Abstract*—Paper concerns accumulation of video-quality losses in multiple HEVC encoding and decoding cycles. The results of extensive experiments with standard video test sequences are reported. General conclusions has been drawn about relative quality losses after each cycle, as well as about total quality loss with respect to first cycle. In general, quality losses after each cycle are decreasing and total quality loss is saturating after several cycles. Total quality losses after several cycles are hardly dependent on sequence content.**

Keywords—video; compression; video coding; multiple cycles; transcoding; HEVC; H.265; MPEG; MPEG-H

I. INTRODUCTION

Research on video coding is a very active topic due to the fact that every few years the new video compression standard is deployed on the market. In video editing workflow and postproduction multiple encoding and decoding of the same material is particularly important.

Currently (March 2013), new video coding standard HEVC (High Efficiency Video Coding) [1] is being finalized by Joint Collaborative Team on Video Coding (JCT-VC) the join body of MPEG (ISO/IEC JTC1/SC29/WG11) and VCEG (ITU-T SG16 WP3). HEVC is the result of many years of research on video compression and intensive collaboration between numerous research teams. The HEVC technology has been designed to be utilized in ultra-high resolution (UltraHD) systems as well in video streaming systems.

When compared to the widely used MPEG-4 AVC/H.264 technology, HEVC allows for about 50% bitrate reduction with preserving the same subjective image quality [2]. During development of HEVC special attention was paid on improving the compression efficiency for high resolution content (HD, FullHD) and future ultra-high resolution content (UltraHD, 4k, 8k). Transmission of high resolution video is still a challenge for telecommunication network and every possibility to reduce transmission burden is highly desirable [3]. Numerous advantages of HEVC over AVC imply that the new standard is likely to be widely adopted in the nearest future.

The HEVC compression efficiency increase over AVC has been achieved by improvements in most of the existing coding tools and by introducing new tools [4]. The most important improvements are focused on inter and intra prediction, interpolation filters, coefficient coding, flexible structure of coding block size (coding units, prediction units and transform units) and variety of unit sizes (4x4 to 64x64 for prediction and 4x4 to 32x32 for transform). The introduction of new compression standard with the rich set of new coding tools raises a question about consequences of multiple encoding and decoding of the same material. Thus, new coding scenarios involving HEVC technique will probably gain a lot of researchers attention.

Research about error accumulation due to multiple encoding-decoding cycles has been already investigated for such a compression standards as MPEG-2 or JPEG. For example in [5] MPEG-2 working in 4:2:2 profile is proposed as a basic standard in professional studios and post-processing industry due to its limited distortion accumulation. In [6,7] analysis of multiple compression cycles in JPEG and JPEG-2000 standards is considered. Only limited number of cycles has been investigated in the above mentioned literature.

II. PROBLEM DEFINITION

In the scenario when decoded material is again encoded, there is no possibility to avoid re-quantization of previously compressed (quantized) signal. The re-quantization causes inevitable and irreversible quality loss. Moreover, when encoding is performed several times on the same material, each cycle introduces new distortion and causes quality losses. Are the quality losses at each cycle additive or they saturate after several cycles of encoding and decoding? Maybe distortion caused by the next cycle cancels out the previous one? In this paper the accumulation of distortion caused by multiple encoding and decoding cycles of the same material is investigated. Additionally the total quality loss relative to the first coding, as well as the number of cycles after which relative quality loss is negligible will be estimated.

III. METHODOLOGY

Original video material was first encoded with HEVC encoder with several predefined QP values and decoded. Quality of decoded material was measured using PSNR metric for luma (Y) component. Next, the decoded material was again encoded by HEVC encoder with exact the same QP value and again decoded. This procedure was repeated multiple times. Each time the decoded video material quality (with respect to original material) and resulting bitrate was measured. In this way data of multiple coding cycles using HEVC standard were gathered.

IV. EXPERIMENTAL MATERIAL

In our experiments we have used 12 SD TV (704x567) 25 Hz and 30 Hz video sequences. These sequences are recommended by an international expert group of ISO/IEC MPEG (Moving Picture Experts Group), which develops standards for coding audio and video, as the official video test sequences. They are also used worldwide by researches in processing, compression and quality evaluating. The used video sequences test set had covered wide range of content characteristics. The following sequences have been used: *bluesky*, *city*, *crew*, *harbour*, *ice*, *pedestrian*, *riverbed*, *rushhour*, *soccer*, *station2*, *sunflower* and *tractor*. As a HEVC codec we have used HEVC reference software in version 9.1 [8]. For each video sequence 4 different QP values of 22, 27, 32, 37 was used. Those QP values reflect commonly used bitrates for TV services. Encoding and decoding was repeated 80 times for each of those QP values resulting in total of 12*4*80 = 3840 coding points.

V. RESULTS

Fig. 1. shows rate distortion plot for 4 QP values (22, 27, 32, 37) for exemplary sequence *bluesky*. For all QP values a small quality degradation along with bitrate reduction can be observed. Additionally a detailed view of quality of decoded material and bitrate after each encoding-decoding cycle for QP=27 value has been shown (Fig. 1, bottom). The numbers of the encoding-decoding cycles are marked on the plot. After a couple of encoding-decoding cycles, change in video quality becomes negligible and change in the bitrate begins to be random (Fig. 1, bottom - zoomed part of the chart). The same can be observed for the rest of the test sequences and QP values.

Relative quality loss with respect to first encoding versus relative bitrate savings with respect to first encoding has been shown on Fig. 2. As we can see, after 80th encoding-decoding cycle for *bluesky* sequence, quality in terms of PSNR drops about -1.2 dB with respect to the first encoding. Detailed view for QP=27 is presented on Fig. 2, bottom. Significant quality loss and bitrate reduction occurs in first few encoding-decoding cycles. After 40 encoding-decoding cycles changes in both quality and bitrate are negligible. Similar observation could be taken for the rest QP values and test sequences.

Relative quality loss (ΔPSNR) after each encoding-decoding cycle for all tested QP values and video sequences has been shown on Fig. 3. Depending on video sequence, total quality loss after 80 encoding -decoding cycles is about:

- 0.70 – 1.80 dB for QP=22,
- 1.05 – 2.05 dB for QP=27,
- 1.10 – 1.90 dB for QP=32,
- 1.15 – 1.65 dB for QP=37,

along with about 5-20% reduction of the bitstream.

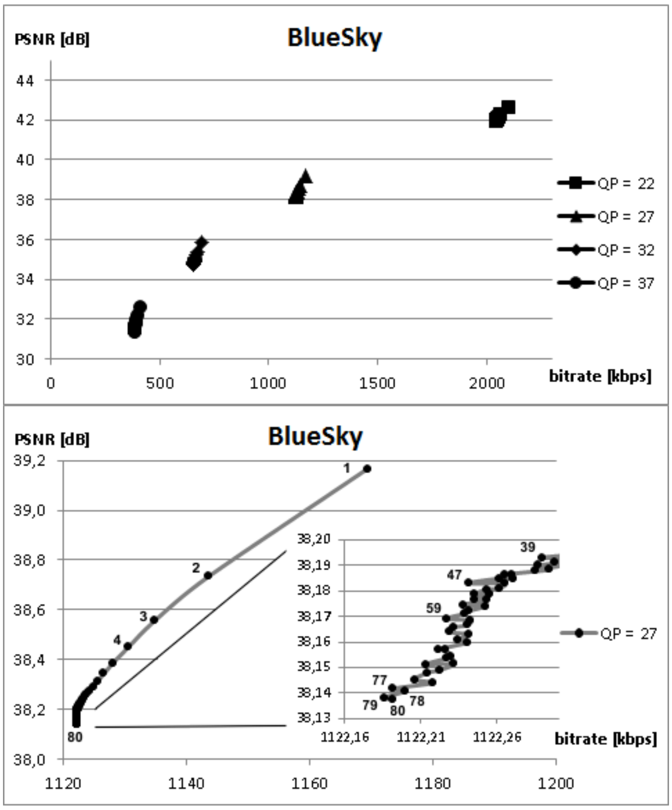

Fig. 1. Results of 80 encoding-decoding cycles of BlueSky sequence: for 4 different QP values (top) and detailed view for QP=27 only (bottom).

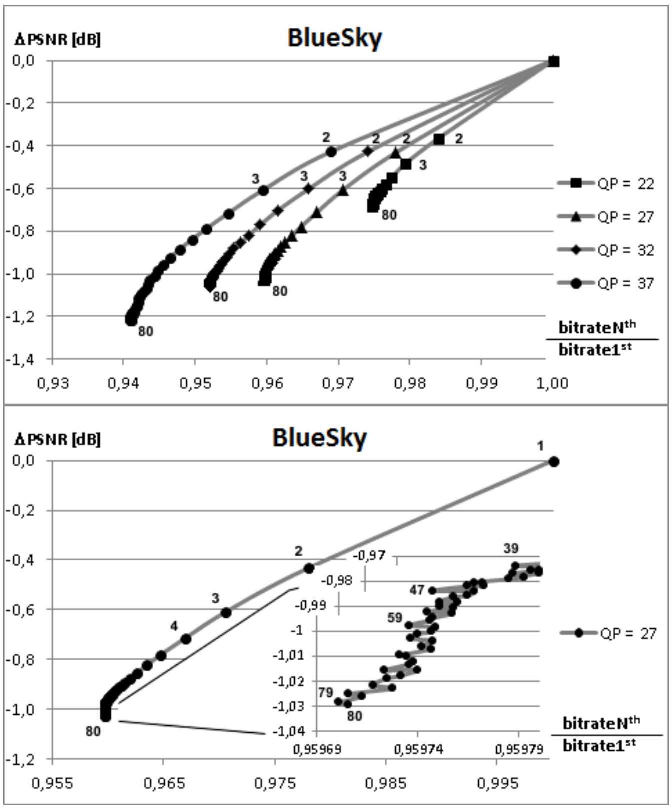

Fig. 2. Quality loss and bitstream reduction after each encoding-decoding cycle relative to first encoding for BlueSky sequence: for 4 different QP values (top) and detailed view for QP=27 only (bottom).

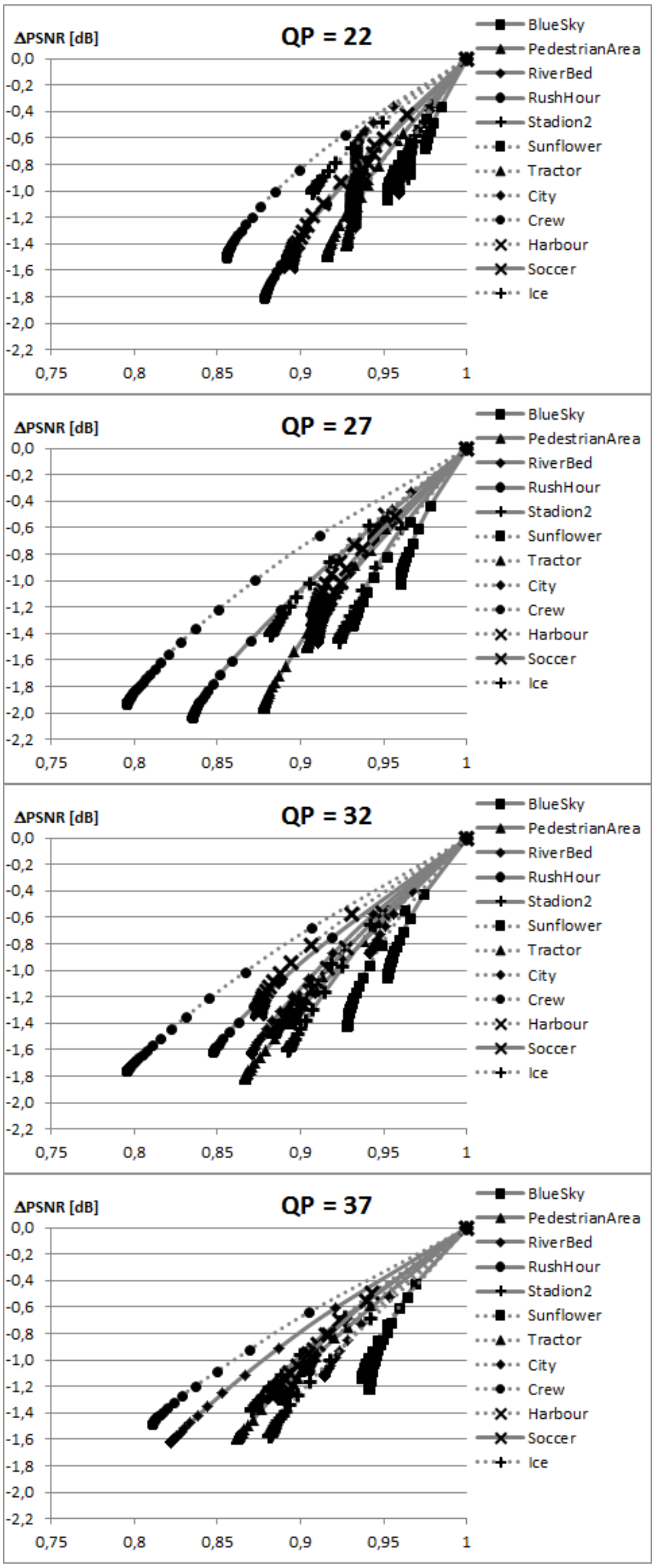

Fig. 3. Quality loss and bitstream reduction after each encoding-decoding cycle relative to first encoding for QP=22,27,32,37.

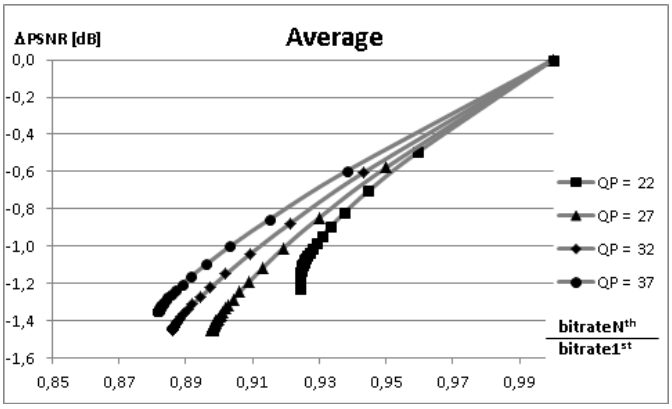

Fig. 4. Quality loss and bitstream reduction after each encoding-decoding cycle relative to first encoding averaged for all test video sequences for different QP values.

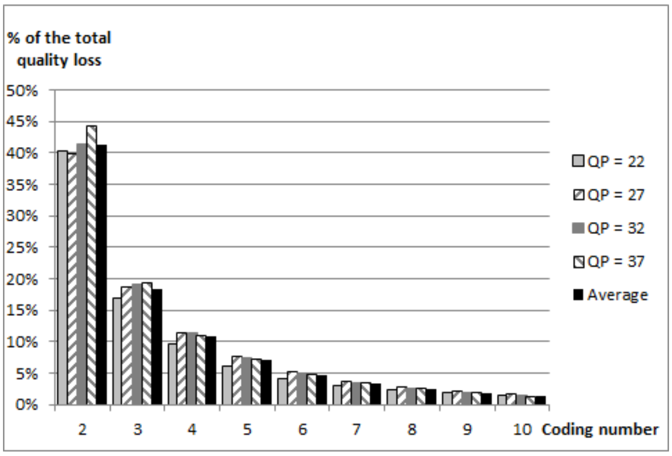

Fig. 5. Percentage of quality loss after each encoding-decoding cycle with respect to the total quality loss after 80 cycles.

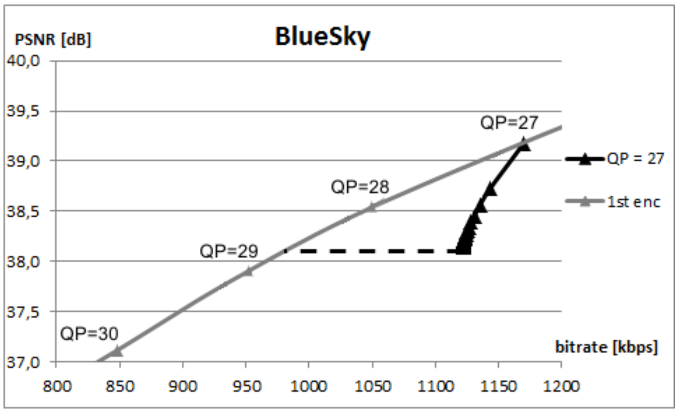

Fig. 6. Comparison of the video quality after 80 encoding-decoding cycles with QP=27 and video quality after first encoding with various QPs. Dashed line represents the same quality in both cases.

Fig. 4 presents averaged quality loss after each encoding-decoding cycle with respect to first encoding. On average quality degradation starts to saturate after 40 cycles and is almost fully saturated after 80 cycles. Total quality loss after 80 cycles is on average -1.5dB and bitrate reduction is on average 10%, both with respect to first encoding. What is interesting accumulation of the distortion (total quality loss) is rather independent on selected QP value.

Moreover, bitrate reduction resulting from multiple encoding-decoding cycles with the same QP value is smaller for high quality images (low QP value) and it increases as QP value increases. Average quality loss after 2nd cycle related to the 1st one and after 3rd related to the 2nd is about 0.5-0.6 dB and 0.2-0.3 dB respectively. More precisely, quality loss after 2nd cycle related to the 1st one is:

- 0.36 – 0.75 dB for QP=22,
- 0.33 – 0.82 dB for QP=27,
- 0.40 – 0.77 dB for QP=32,
- 0.42 – 0.74 dB for QP=37.

Fig. 5 presents quality loss at each encoding-decoding cycle as a percentage of the total quality loss (after 80 cycles with respect to first one) for the first few cycles. Second encoding-decoding cycle is responsible for 41% of the above mentioned total quality loss (on average).

We compared the quality (in terms of PSNR) of the sequence after 80 encoding-decoding cycles with the sequence quality after first encoding (Fig. 6). In order to encode a sequence with the same quality as after 80 encoding-decoding cycles, the QP value must be increased by 1.9 on average. In other words, decreasing QP value by 1.9 assures, that quality of the video after several encoding-decoding cycles will be no worst that it would be after first encoding with unmodified QP value.

VI. CONCLUSIONS

In the paper the accumulation of distortion caused by multiple encoding and decoding of the same material with constant QP value has been investigated. The main observation is that quality loss introduced by multiple encoding and decoding saturates after several cycles. On average, after 40 encoding-decoding cycles the quality losses and bitrate changes are negligible.

Moreover, total quality loss (i.e. quality loss after 80 encoding-decoding cycles with respect to the first encoding) is in range of 0.68 – 2.04 dB (1.4 dB on average). Total quality loss is almost independent of QP value tested. About 41% of the total quality loss is due to quality loss introduced by first encoding. Bitrate reduction after 80 cycles with respect to first encoding is about 10% and it is almost fully saturated.

Quality loss introduced by multiple coding cycle with constant QP value can be compensated by using lower initial QP value (higher initial quality). For 80 encoding-decoding cycles initial QP value has to be decreased by about 2.

ACKNOWLEDGMENT

Research project was supported by The National Centre for Research and Development, Poland. Grant no. NR02-0080-10/2010.

REFERENCES

[1] B. Bross, W.-J. Han, J.-R. Ohm, G. J. Sullivan, Y.-K. Wang, T. Wiegand, "High Efficiency Video Coding (HEVC) text specification draft 10 (for FDIS & Last Call)", Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11, Geneva, CH, Jan. 2013.

[2] J-R. Ohm, G.J. Sullivan, H. Schwarz, T.K. Tan, T. Wiegand: "Comparison of the coding efficiency of video coding standards - Including High Efficiency Video Coding (HEVC)", IEEE Transactions on Circuits and Systems for Video Technology, vol. 22, no. 12, pp. 1669–1684, Dec. 2012.

[3] F. Bossen, B. Bross, K. Suhering, D. Flynn: "HEVC Complexity and Implementation Analysis", IEEE Transactions on Circuits and Systems for Video Technology, vol. 22, no. 12, pp. 1685–1696, Dec. 2012.

[4] G.J. Sullivan, J.-R. Ohm, W.-J. Han, T. Wiegand, "Overview of the High Efficiency Video Coding (HEVC) Standard", IEEE Transactions on Circuits and Systems for Video Technology, vol.22, no.12, pp. 1649-1668, Dec. 2012.

[5] C. Horne, T. Naveen, and A. Tabatabai, "Study of the characteristics of the MPEG2 4:2:2 profile-application of MPEG2 in studio environment", IEEE Trans. Circuits and Systems for Video Technology, Vol. 6, no. 3, pp. 251-272, 1996.

[6] R.L. Joshi, M. Rabbani, and M.A. Lepley, "Comparison of multiple compression cycle performance for JPEG and JPEG2000", Proc.SPIE, vol. 4115, pp. 492-501, 2000

[7] K. Rakowski, M. Domański, "Experimental analysis in multiple image coding-decoding cycles with color transformations," Proceedings of 10th International Workshop on Systems Signals and Image Processing, IWSSIP'2003, Prague, pp. 69-72.

[8] HEVC test model reference software – available online: https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/