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Benchmarking the Encoding Efficiency of H.265/HEVC and H.264/AVC

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Abstract: This paper deals with the currently developing video encoding standard, namely the H.265/HEVC. The scope of this paper is to compare the encoding and compression efficiency of the new standard in comparison to its predecessor H.264/AVC and more specifically to validate if the main objective of the new standard, which is to double the compression efficiency of the bit stream without degradating the quality of the encoding compression, is satisfied.

Keywords: H.265, H.264, HEVC, AVC, PSNR.

1. Introduction

Lately the interest for multimedia content and services on demand has been increased significantly, creating the need for the provision of high quality services in terms of content and availability. To meet the industry requirement of standardizing existing video techniques, video coding standards were developed by two international organizations, ITU-T and ISO/IEC. The family of ISO/IEC MPEG standards includes MPEG-1, MPEG-2 MPEG-4, and MPEG-4 Part 10 (AVC) [1],[2]. ITU-T H.26x series standards consist of H.261, H.263, and H.264.

The evolution of video coding standards is analogous to the technological progress and the marketing needs toward improving the coding efficiency of video compression technologies. For example, the state of art video coding standard H.264/ AVC [1], jointly developed by ITU-T Video Coding Experts Group (VCEG) and ISO/IEC Moving Picture Experts Group (MPEG), is reported to achieve gains in compression efficiency up to 50% to its predecessor MPEG-2.

However, the increasing popularity of high definition TV, video delivery on mobile devices, and other multimedia applications creates new demands for video coding standards for even higher encoding efficiency and achieved video quality.

To face the new challenges, both MPEG and VCEG launched their next-generation video coding project, which potentially could be either an extension of H.264/AVC or a brand new standard. Finally in 2010, we lead to the successor of H.264/AVC and the development of a new video coding standardization process has been initiated by both MPEG and VCEG called High Efficiency Video Coding (HEVC)/H.265. This new standard is expected to satisfy the ever-increasing requirements for cost effective video encoding process in terms of better video quality compression efficiency, video resolution, frame rates and computational complexity.

The HEVC's main goal is the outperformance of the AVC in terms of video compression efficiency, providing two times better video compression performance, which means that for the same video quality, in terms of noise level and dynamic range compared to AVC, the encoding efficiency (i.e. the compression ratio of the data will be doubled).

Thus, the newly introduced HEVC/H.265 encoding standard promises significantly better performance and compression efficiency in comparison to the previous AVC/H.264 standard. For this reason, it is created the need to benchmark the performance of HEVC in comparison to AVC in order to monitor the development of the new standard and if these qualitative objectives are satisfied or not. Thus, this paper deals with the benchmarking of the HEVC and AVC in terms of video quality and encoding performance in order to evaluate if the developing HEVC standard achieves (even partially) its main target: To double the encoding efficiency (i.e. maintaining the same deduced quality for the half in size encoded video signal in comparison to AVC standard).

For this reason, in order this paper to benchmark the encoding efficiency of the two video encoding standards under test (i.e. HEVC and AVC) a set of video signals was used as input to both the encoders. The experimental set of the test signals cover different spatiotemporal activity levels, making the benchmarking framework of this paper complete considering the diversity of the signals under test. For the quality assessment part, for benchmarking purposes, the most appropriate assessment methods the PSNR metric [3],[4], which although is not correlated with the actual perceptual video quality of the encoded signal, it however provides an accurate benchmarking assessment of the encoding efficiency for the cases where two different codecs are compared.

Upon this introductory section, the rest of the paper is organized as follows: Section 2 introduces the main novel features of H.265. Section 3 describes the encoding process of H.264 and H.265 signals. In section 4 the benchmarking between the two signals is performed. Finally Section 5 concludes the paper.

2. Introducing H.265/HEVC Features

In this section we report the basic new features of the new HEVC video encoding standard. Considering the standard is still under development, possible more features will be added in the near future or the reported ones may be altered in the next versions of the codec versions.

2.1 Block-Based Coding

The HEVC continues to implement the block-based hybrid video coding framework, with the exception of the increased macroblock size (up to 64x64) compared to AVC.

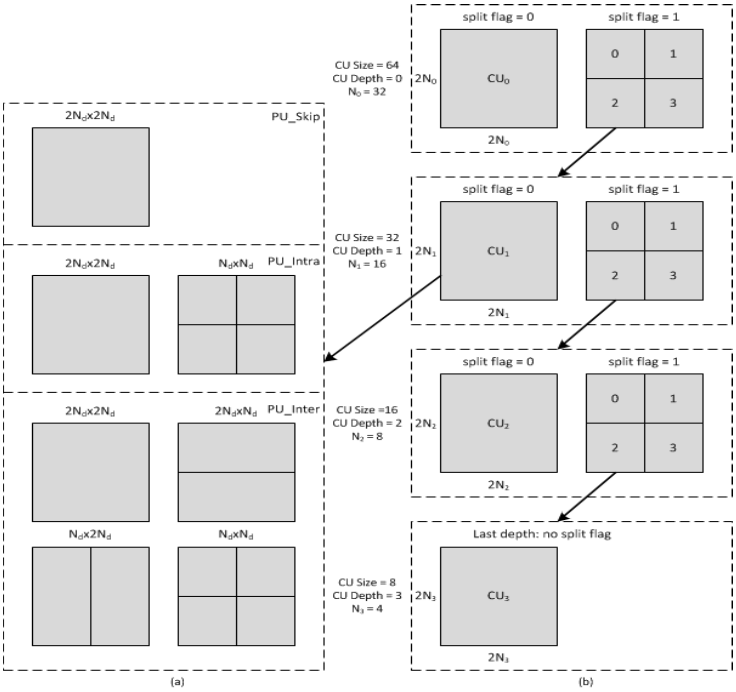

Figure 1. Recursive quadtree representation of CU

Also three novel block concepts are introduced, namely: the coding unit (CU), the prediction unit (PU) and the transform unit (TU). CU is the basic coding unit like the H.264/AVC's macroblock and can have various sizes but is restricted to be square shaped.

The general outline of the coding structure is formed by various sizes of CUs, PUs and TUs in a recursive manner, once the size of the largest coding unit (LCU) and the hierarchical depth of CU are defined. Given the size and the hierarchical depth of LCU, CU can be expressed as a recursive quadtree representation as it is depicted in Figure 1, where the leaf nodes of CUs can be further split into PUs or TUs.

The introduction of larger block structures is one of the most important elements for higher compression performance in high resolution videos, due to the flexible sub-partitioning mechanisms. Respectively, the model defines CUs which sub-partition a frame into equal or variable size rectangular regions. At the PU level, either intra-frame or inter-frame can be selected.

2.2 Intra-Prediction in HEVC

The current intra prediction technique in HEVC unifies two simplified directional intra prediction methods: the Arbitrary Direction Intra and the Angular Intra Prediction. The unified intra prediction technique enables a lower-complexity method in which parallel processing can be achieved, where samples of already decoded adjacent Pus are used, the signalling of the mode is produced from the modes of adjacent PUs (horizontal, vertical or depending on the block size up to 28 angular directions) and syntax indicators.

2.3 Inter-Prediction in HEVC

The inter prediction in HEVC uses the frames stored in a reference frame buffer (with a display order independent prediction, as in AVC), which allows multiple bi-direction frame reference. A reference picture index and a motion vector displacement are needed in order to select reference area. The merging of adjacent PUs is possible, by the motion vector, not necessarily of rectangular shape as their parent CUs. In order to achieve encoding efficiency, skip and direct modes similar to the AVC ones are defined, and motion vector derivation or a new scheme named motion vector competition is performed on adjacent PUs. Motion compensation is performed with a quarter-sample motion vector precision. At TU level (which commonly is not larger than the PU), an integer spatial transform (with range from 4x4 to 64x64) is used, similar in concept to the DCT transform. In addition a rotational transform can be used for block sizes larger than 8x8, and apply only to lower frequency components. In AVC scaling, quantization and scanning of transform are performed in a similar way.

At CU level, an adaptive loop filter (ALF) can be applied prior to copying the frame into the reference picture buffer. This is a FIR filter whose main purpose is to minimize distortion relative to the original picture, and its filter coefficients which are encoded at slice level. Additionally a deblocking filter is operated within the prediction loop (similar to the AVC deblocking filter design). After applying these 2 filters the display output is written to the picture buffer.

2.4 Entropy Coding in HEVC

The HEVC defines 2 context-adaptive entropy coding patterns, one for the higher-complexity mode and one for the lower-complexity mode. The lower-complexity mode is based on a variable length code (VLC) table selection for all the syntax elements, while using a particular code table which is picked in a context-based scheme depending on previous decoded values. This design is very similar to the CALVC pattern from AVC, but enables even simpler implementation according to its more systematic structure. A re-sorting of code table elements can be used as a supplementary compression improvement.

The higher-complexity design uses a binarization and context adaptation pattern similar to the AVC entropy coder, CABAC, but with the difference of using a set of variable-length-to-variable-length codes (indexing a variable number of bins into a variable number of encoded bits) instead of using and arithmetic coding engine. This is performed by applying a bank of parallel VLC coders – each of which is responsible for a certain range of odds of binary events (which area referred to as bins). The coding performance can be better parallelized and has higher throughput per processing cycle in software of hardware implementation than CABAC, although being very similar to it. It must be noted that the compression performance of this design can be significantly higher than the lower-complexity VLC.

3. Video Coding of HEVC and AVC signals

3.1 Test Signals and Encoding Process

For the evaluation process 3 reference video clips were used (Bubbles, Horse Race, BQ Square), which represent various levels of spatial and temporal activity. A representative snapshot of each signal is depicted on Figure 2.

The test signals have spatial resolution 416x240 and for the experimental needs of this paper were encoded from their original uncompressed YUV format to ISO AVC Baseline Profile and to the following profiles of HEVC, namely: i. Random Access Profile (RAP), ii. Random Access Low Complexity Profile (RALCP), and iii. Low Delay Profile (LDP). Across all the encoding process the reference software was used for both the AVC and HEVC coding. Especially for HEVC the HEVC Test Model (HM) Reference Software 1.0 was used.

Figure 2. The test signals

In order to maintain and achieve an ideal comparison between the various profiles, it is necessary all the profile configurations to have identical or very similar parameter values. For this reason, the GOP structure for all the encoding profiles and between the two encoding methods consisted of either I, P or B, ensuring by this method the benchmarking of both Intra and Inter-coding efficiency between AVC and HEVC standard profiles.

The Quantization Parameter (QP), for I and P frames, has a great impact on visual quality and compression rate, as it regulates how much spatial detail is maintained. For this reason, across all the experimental tests of this paper, the QP for both I and P frames were set to the value of 32 in both AVC and HEVC profiles, so as to accomplish equal encoding conditions.

3.2 Encoding process duration of the test signals

In the following table it is presented the relative average duration of the encoding process for all the encoding profiles of HEVC with respect to the duration that the system needed for the encoding of AVC Baseline profile. As it can be deduced the duration requirements of the HEVC encoding process are much higher for all the profiles in comparison to the AVC.

Table 1. Relative Encoding Time in Comparison to AVC Baseline Profile required encoding time

	RAP	RALCP	LDP
Horses	4.85	4.45	3.76
Bubbles	3.99	3.84	3.46
BQSquare	3.98	3.80	3.70

Based on the results of Table 1, it is deduced that the HEVC profiles have greater demand in terms of the time that is needed in order the encoding process to be completed in comparison to the AVC baseline profile. According to the experimental process of this paper, the time needed for HEVC to perform the encoding process is at an average of 4x times greater than the time needed for AVC to complete the encoding process for the same test signals. Additionally it is observed that the spatiotemporal activity level of the video content plays, as expected, a significant role in the time needed, considering that the Horses reference video clip, which has a much richer motion-wise theme comparing to the Bubbles and BQSquare ones, needs at the RAP at least 4.45 times the respective time that needs the AVC Baseline profile in order to complete the encoding process, while the rest two test signals score significantly below the 4x times greater threshold.

4. Benchmarking of HEVC and AVC signals

4.1 Compression Efficiency of HEVC vs. AVC

In this section, we research the compression efficiency of the HEVC algorithm in comparison to the AVC for the test signals under test, when same encoding parameters have been selected (i.e. the QP for both I and P frames were set to the value of 32 in both AVC and HEVC profiles) [5].

Table 2. Compression Efficiency improvement of HEVC encoded signals vs. AVC encoded signals

	RAP	RALCP	LDP
Bubbles	49%	44%	30%
BQSquare	66%	49%	36%
Horses	51%	48%	35%

As it can be observed from the results of Table 2, the encoded signals under the same encoding settings, appear to have almost double encoding efficiency in HEVC case in comparison to AVC one. The results of this table confirm the objective of the new encoding standard that aims enhance by 50% the encoding ratio in comparison to the AVC encoding standard.

4.2 Encoding Efficiency of HEVC vs. AVC

This section presents the experimental results of the comparison between HEVC and AVC encoded signals by the use of the PSNR metric. Across the encoding process of all the profiles of the encoding standards, the encoding parameters were remained constant in order to be possible the quantitative comparison of the encoding efficiency.

In Figures 3, 4 and 5 are depicted the PSNR vs. Frames (time) graphs of the three test signals encoded by H.265/HEVC profiles in comparison with the H.264/AVC baseline profile. Across all the encoded signals, the encoding parameters have remained constant in order to be possible the comparison between the various profiles and the different signal types.

As it can be deduced by these figures, the encoding efficiency of the new HEVC/H.265 is similar to the AVC/H.264, which is in line with the objective of the new standard that aims to maintain the encoding efficiency of the previous encoding standard (i.e. AVC), while it doubles the compression efficiency of the bitstream, as we show in the previous section.

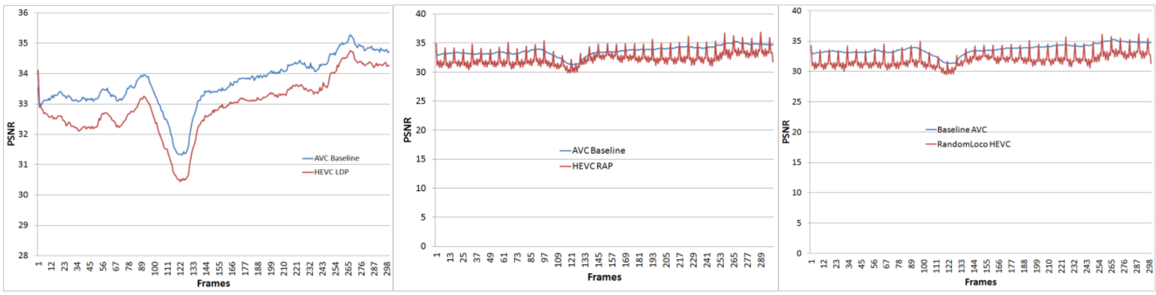

Figure 3. PSNR vs. Frames of test signal Horses for HEVC RAP, RALCP, LDP vs AVC Baseline

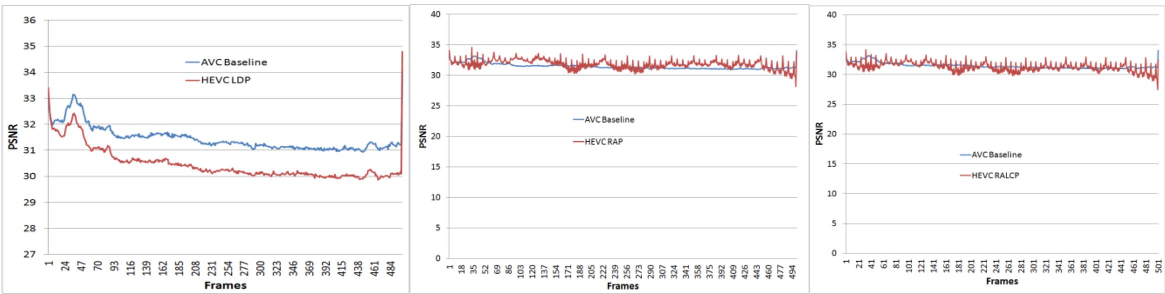

Figure 4. PSNR vs. Frames of test signal Bubbles for HEVC RAP, RALCP, LDP vs AVC Baseline

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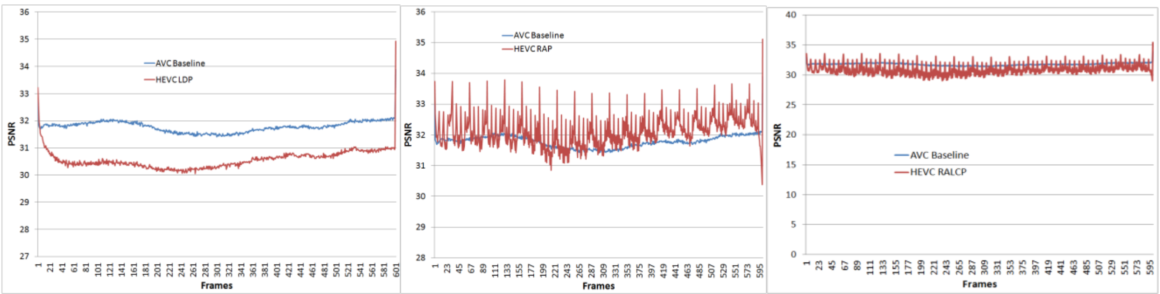

Figure 5. PSNR vs. Frames of test signal BQSquare for HEVC RAP, RALCP, LDP vs AVC Baseline

Commenting further on the experimental results of the above Figures, it can be also deduced that the HEVC standard performs worse on high-motion video sequences, where it achieves a lower average PSNR value in comparison to AVC encoding. However, for the rest two test signals, the performance of the HEVC is better or similar to the AVC baseline's.

Finally, the observation leads us to the conclusion that although the average PSNR score of the HEVC profiles is similar to the respective on of the AVC, the HEVC encoding performance creates spikes and peaks that outperform significantly the AVC performance. So, currently the AVC encoding performance is smoother in comparison to the HEVC that appears to have greater variance.

5. Conclusions

This paper has researched the encoding and compression efficiency of the newly developing video encoding standards HEVC/H.265. The experimental results of this paper have confirmed that the main objective of the new standard to double the compression efficiency but maintaining the same quality in comparison to the previous standard (i.e. AVC) has been achieved.

6. Acknowledgement

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References

[1] ISO/IEC International Standard 14496-10, Information Technology – Coding of Audio-Visual Objects – *Part 10: Advanced Video Coding*, third ed., Dec. 2005, corrected version, March 2006.

[2] G. J. Sullivan and T. Wiegand, *"Video compression – from concepts to the H.264/AVC standard,"* Proceedings of the IEEE, vol. 93, no. 1, pp. 18-31, Jan. 2005.

[3] F. Pereira and T. Alpert, *"MPEG-4 Video Subjective Test Procedures and Results"*, IEEE Transactions on Circuits and Systems for Video Technology. Vol. 7(1), pp. 32-51, 1997.

[4] ITU *"Methodology for the subjective assessment of the quality of television pictures"*, Recommendation ITU-R BT.500-10, 2000.Tavel, P. 2007 Modeling and Simulation Design. AK Peters Ltd.

[5] M. Pinson and S. Wolf, *"Comparing subjective video quality testing methodologies"* Visual Communications and Image Processing 2003. Edited by Ebrahimi, Touradj; Sikora, Thomas. Proceedings of the SPIE, Volume 5150, pp. 573-582 (2003).

[6] HEVC reference toolkit available for download version directory "https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/tags/"

[7] Link for the reference test video signal "ftp://ftp.tnt.uni-hannover.de/testsequences"