High Efficiency Video Coding: Analysis and Characterization

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***Abstract*—This paper analyzes the new video compression standard, High Efficiency Video Coding (HEVC). The main goal of this standard is to save around 50% of the bit rate keeping the same quality as its predecessor H.264/AVC. This paper analyzes also the quality given by HEVC reference video codec (HM) in terms of PSNR and the complexity of the codec stages in terms of execution time.**

Keywords-High Efficiency Video Coding, encoder, decoder, Test Model (HM), PSNR, complexity analysis.

I. INTRODUCTION

The High Efficiency Video Coding (HEVC) is the newest video coding standard, developed by ITU-T VCEG and ISO/IEC MPEG working together in a partnership called Joint Collaborative Team on Video Coding (JCT-VC). The first edition of this standard was approved in April 2013 and published in June 2013 [1]. Currently 3 profiles have been defined in the standard: Main, Main 10 and Main Still Picture. The Main profile is meant for typical video applications, the study in this paper is based on it. Main 10 profile is the extension for higher bit depth, e.g., from 8 up to 10 bits. And the Main Still profile is a subset of the Main profile and it is used for single images (only intrapicture coding).

The coding efficiency of HEVC has been designed to deal with the issues explained previously. It is significantly better than its predecessor H.264/AVC. Coding efficiency means the ability to minimize the bit rate need for a specific video quality, or formulated in another way, to maximize the video quality for a specific bit rate. The evaluations in [4] show that HM 6.0 which corresponds with the Committee Draft of HEVC, on average, reduces bit rate over H.264/AVC by almost 37% with an equivalent quality. These results rely on objective quality assessments, Peak Signal to Noise Ratio (PSNR).

This paper provides an overview of the technical features and characteristics of the HEVC standard, highlighting the differences with H.264/AVC. Moreover, using the test model HM 8.0 and the tool Intel VTune, the standard will be characterized by rate distortion and a complexity analysis based on the time used for each coder stage.

II. HEVC CODING DESIGN AND KEY FEATURES

HEVC uses the same “hybrid” structure (inter and intrapicture prediction and two-dimensional transform coding) as in all previous video standards since H.261 but it introduces improvements in every stage.

A. *Coding Tree Units and Conding Tree Block structure*

In previous standards, the coding unit was the macroblock (one 16x16 block of luma samples and, for the 4:2:0 format, two 8x8 blocks of chroma). In contrast, HEVC uses Coding Tree Unit (CTU). The CTU consists of Coding Tree Blocks (CTBs) for luma and chroma. A CTB for luma has LxL samples and the corresponding CTBs for chroma L/2xL/2. The value of L can be 16, 32 or 64. In that way, HEVC offers more flexibility than H.264/AVC. The CTBs are then partitioned into coding blocks (CBs). They are always square. One luma CB and its associated two chroma CBs is referred to as a Coding Unit (CU). A CTB may contain only one CU or may be split in multiple CUs. At CU level, there is additional partitioning into prediction units (PUs) and a tree of transform units (TUs).

B. *Prediction Units and Prediction Block*

Depend on the prediction used the CB can be split. If the intra prediction mode is used, the size of the Prediction Block (PB) is the same as the size of the CB, except for the smallest one, in that case, the CB can be divided in four PBs so each of them can be coded with a different intra mode. If the inter prediction is used, the CBs can be split in 2 or 4 (only if the CB size is the smallest allowed).

C. *Transform Units and Transform Block*

The prediction residual is coded using block transforms. The CB residual may be identical to the Transform Unit (TU) or may be further partitioned into smaller TBs. HEVC allows that a TB covers several PBs in a CU using inter prediction. In that way, the benefits of the codification are maximized.

D. *Intrapicture Prediction*

The intrapicture prediction in HEVC is similar to the one employed in H.264/AVC but extending the number of possible directions. HEVC uses 33 directional modes (against the 8 modes used in H.264/AVC), plus flat and planar modes.

E. *Interpicture Prediction*

Similar to H.264/AVC, quarter sample precision is used for luma and eighth sample precision for chroma (when 4:2:0

format is used). For luma samples, HEVC employs an 8-tap filter for the half-sample positions and a 7-tap filter for the quarter-sample positions. H.264/AVC, in contrast, uses a 6-tap filter for the half-sample positions and then averaging to get the quarter-sample positions. The process for the chroma samples is similar to the one for luma samples but using a 4-tap filter. In contrast, H.264/AVC employs a 2-tap bilinear filter.

HEVC employs Advanced Motion Vector (MV), a new merge mode and improved direct and skip modes.

F. *Entropy Coding*

HEVC uses a single method of entropy coding, Context Adaptive Binary Arithmetic Coding (CABAC), instead of two possible methods as in H.264/AVC, Context Adaptive Variable Length Coding (CAVLC) or CABAC. The core is similar to the one in H.264/AVC but some improvements have been added to improve the throughput, the compression efficiency and memory requirements.

G. *In-loop Filters*

Two filters have been integrated before writing the reconstructed picture in the decoded buffer, a Deblocking Filter (DBF) and a Sample Adaptive Offset (SAO) filter. The DBF is similar to the one in H.264/AVC but its design has been simplified in the decision making and filtering process to assist the parallel processing. The SAO filter is a new element and is applied after the DBF. The SAO filter is applied to all of the samples, it is a nonlinear amplitude mapping and its goal is to improve the reconstructed samples adding an offset value. SAO gives an additional refinement after DBF.

III. Functional Analysis

The examined software is HM 8.0 [5] using Main Profile (MP). HM 8.0 describes HEVC Draft International Standard. Currently, the last version is HM 11.0 and it represents the standard. The differences between HM 8.0 and HM 11.0 for MP are expected to be marginal.

A. *Test Conditions and Sequences*

Table I shows the test conditions (All-Intra (AI), Random Access (RA), Low-delay P (LP) and Low-delay B (LB)) and the 8-bit sequences used for the analysis. For these configurations, QP values of 22, 27, 32 and 37 are used.

TABLE I. Test Conditions and Sequences

Format	**Seq. Name**	**Fram. No.**	**Fram. rate**	**Configurations**			
				AI	***RA***	***LB***	***LP***
832x48 WVGA	RaceHorses	300	30 fps	x	x	x	x
416x240 WQVGA	BlowingBubbles	500	50 fps	x	x	x	x
352x288 CIF	Mobile	300	30 fps	x	x	x	x
176x144 QCIF	Claire	494	30 fps	x	x	x	x

IV. Results: PSNR-Bit Rate and Complexity Analysis

Based on the PSNR-bit rate results got in this analysis, for all the sequences and configurations under test, in general, the bit rate decreases together with the PSNR when the QP increases. AI configuration gives the better PSNR but the bit rate is 9 times bigger than in the rest of configurations and the PSNR is only 1-3 dB better. In another side, RA gives better results than LB, and this one better than LP. The reason because RA provides the best results is that it introduces an Intra picture every 32 pictures, for this kind of pictures the QP applied is lower so the final quality is increased. LB shows better results than LP due to the fact that the B pictures get better compression than the P ones so for the same bit rate, the quality is bigger in LB.

According to the data extracted in the complexity analysis developed with Intel VTune Amplifier, the coding under AI configuration has the lowest complexity due to the inter prediction does not exist in this case. Also, for the same reason, the computational load in T/Q/IT/IQ and EC is bigger for AI than in the rest of configurations. The inclusion of the inter prediction increase the complexity in RA, LB and LP, 2.42 times the time required for AI. The QP values have also an impact in the time. Increasing the QP from 22 to 27, the time is reduced between 7% and 16%; from 27 to 32, the reduction is between 10% and 21%; and finally, from 32 to 37, the time is reduced between 9% and 21%.

V. Conclusions

In this paper, it has been presented the results of the Rate Distortion analysis of HM 8.0 under the AI, RA, LB and LP configurations. They testbenches were executed in each configuration using QP values of 22, 27, 32 and 37. The resolutions of the test sequences varied from QCIF up to WVGA. The Rate Distortion analysis relied on PSNR. A complexity analysis has been also presented in this document.

HEVC represents a flexible, reliable and robust solution which introduces a number of advances in video coding technology. The complexity increase is affordable but, based on the results of the analysis, a lot of work is required in the market of the mobile devices where the power consumption and the size of the chip are essential. In general, the complexity of the standard is in the inter prediction, due to the motion estimation, so it could be a good candidate to try to optimize the implementation.

References

[1] Recommendation ITU-T H.265 “High efficiency video coding”, 2013.

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[4] Comparative Rate-Distortion-Complexity Analysis of HEVC and AVC Video Codecs. Jarno Vanne, Marko Viitanen, Timo D. HÄmäläinen, Antti Hallaputo, December 2013.

HM HEVC Reference Sofgtware v8.0, in line, available in: https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/tags/HM-8.0/