

STILL PICTURE CODING PERFORMANCE OF H.265/HEVC AND SCALABLE H.265/HEVC

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ABSTRACT

High Efficiency Video Coding (H.265/HEVC) is a new video coding standard developed jointly by ITU-T/VCEG and ISO/IEC/MPEG. The standard finalized in January 2013 offers significant benefits in video quality and achieves similar visual quality as earlier standards, but using half the bitrate. H.265/HEVC specifies a “Main Still Picture” profile for efficient representation of still pictures using the same intra coding tools present in the H.265/HEVC video profiles. The “Main Still Picture” profile is expected to find extensive use in still-picture applications as the same underlying codec present for video decoding can be used to decode still pictures as well. This paper analyzes the coding performance of the still picture coding performance of H.265/HEVC and compares it with earlier standards, such as JPEG, JPEG-XR and JPEG-2000. In addition, performance of the draft scalable extension of H.265/HEVC (SHVC) is analyzed for coding still pictures in a scalable manner. From the objective results obtained using the JCT-VC test set, it is shown that on average JPEG uses 2.3 times more bits, JPEG-XR uses 1.6 times more bits and JPEG-2000 uses 1.4 times more bits than H.265/HEVC for coding still pictures. It is also observed that the improvement H.265/HEVC brings is larger at high resolutions and at lower bitrates, compared to lower resolutions and high bitrates.

Index Terms— H.265, HEVC, still picture, video coding, image coding

1. INTRODUCTION

The High Efficiency Video Coding (H.265/HEVC) standard was developed by the Joint Collaborative Team on Video Coding (JCT-VC), which is comprised of the ITU-T Video Coding Experts Group and the ISO/IEC Moving Picture Experts Group and it was technically finalized in January 2013 [1]. Similar to earlier video coding standards, H.265/HEVC employs a hybrid video coding approach, where a prediction signal is first formed by inter and intra prediction means and the residual signal is then coded with transform coding. H.265/HEVC achieves similar visual quality as H.264/AVC but roughly at half the bitrate [2]. The gains in coding efficiency are achieved by improving and redesigning different parts of the codec, such as flexible quad-

tree partitioning of coding blocks, improved in-loop and interpolation filtering, more flexible intra prediction, etc. A more detailed explanation of the new coding tools of H.265/HEVC can be found in [2].

In this paper, an extensive performance analysis of the H.265/HEVC Still Picture Profile is presented. For this purpose, the test images are encoded at three different bitrate ranges (low, medium and high) using H.265/HEVC, JPEG, JPEG2000 and JPEG-XR; and their coding efficiencies are compared along with visual examples. In addition, lossless coding performance of H.265/HEVC is analyzed as that is one important still image application. Some visual examples are also shown. Finally, the performance of the draft scalable extension of H.265/HEVC is analyzed for spatial scalable coding applications of still pictures. Experimental results show that on average JPEG uses 2.3 times more bits, JPEG-XR uses 1.6 times more bits and JPEG-2000 uses 1.4 times more bits than H.265/HEVC for coding still pictures at aligned objective quality. It is also observed that the improvement H.265/HEVC brings is larger at high resolutions and at lower bitrates, compared to lower resolutions and high bitrates. Visual examples show that H.265/HEVC exhibits much less blocking and ringing artifacts, compared to other standards which increases the subjective performance. For scalable coding of still pictures, H.265/HEVC achieves 27.7% gain compared to simulcast on average.

This paper is organized as follows. Section 2 presents an overview of H.265/HEVC standard with emphasis on intra coding tools. In addition, an overview is presented for the draft scalable extension of H.265/HEVC currently being standardized at JCT-VC. Section 3 describes the details of the number experiments. Section 4 presents the experimental results and Section 5 concludes the paper.

2. STILL PICTURE PROFILE OF H.265/HEVC AND SCALABLE EXTENSIONS

H.265/HEVC defines a specific profile, named as Main Still Picture profile, for still picture compression. A bitstream complying with this profile consists of a single IDR picture coded with H.265/HEVC Main profile intra coding tools. These tools are designed to achieve high coding efficiency with low computational complexity and low memory

bandwidth requirements [3]. The coding architecture and tools defining the profile can be summarized as follows:

- Angular intra prediction with 33 spatial prediction directions to efficiently model the directional structures. The prediction process is designed to have low computational requirements and to be consistent across block sizes and prediction directions. Figure 1 illustrates the angular intra prediction modes used in H.265/HEVC.
- Planar prediction mode that preserves the continuities along block boundaries to efficiently generate smooth sample surfaces.
- Filtering of the prediction block boundary samples to reduce blocking and contouring artifacts.
- Prediction mode dependent residual transform coefficient scanning to adapt the entropy coding characteristics to the expected distribution of active coefficients.
- Intra mode coding based on contextual information
- Quadtree-based coding structure following the H.265/HEVC block coding architecture

In addition, the H.265/HEVC intra coding process shares several processing steps with H.265/HEVC inter coding. This processing includes for example transform coding, quantization, entropy coding, reduction of blocking effects and applying sample adaptive offsets (SAO).

JCT-VC is currently working on extending H.265/HEVC to support spatial and quality scalability use-cases. The initial software model for scalable H.265/HEVC (SHVC) [4] performs enhancement layer coding by predicting sample values either utilizing the single layer H.265/HEVC approach or alternatively using the samples from the reconstructed and upsampled base layer. JCT-VC is currently in the process of evaluating various tools to further improve the coding efficiency of SHVC.

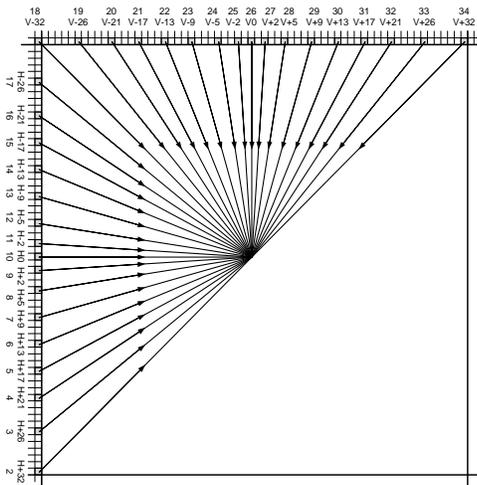


Figure 1 Illustration of the H.265/HEVC angular intra prediction modes.

3. DESCRIPTION OF EXPERIMENTS

In order to evaluate the still picture coding performance of H.265/HEVC standard, extensive experiments have been performed using test pictures coded at various rate points. The details of these experiments are provided below.

3.1. Test Pictures

For all of the coding experiments, first picture of the each JCT-VC video test sequence is used [7]. JCT-VC test-set consists of 24 sequences arranged in different classes according to their resolution and characteristics.

Table 1 JCT-VC test-set and respective characteristics

Class	Resolution	Characteristic
Class A	2560x1600	Cropped 4Kx2K sequences to simulate Ultra HDTV services
Class B	1920x1080	High resolution sequences to simulate streaming and broadcast services
Class C	832x480	Medium resolution sequences to simulate mostly mobile video services.
Class D	416x240	Low resolution sequences to simulate mobile services to resource constrained devices.
Class E	1280x720	720p sequences to simulate video conferencing applications
Class F	1024x768 1280x720	Computer generated content to simulate screen content coding

3.2. Evaluation methodology

The test pictures mentioned above are coded at various rate points using H.265/HEVC, JPEG, JPEG-XR and JPEG2000 standards. In order to see the gains of H.265/HEVC, three different bitrate ranges are used.

Low bitrate range: For this test, first each picture is coded with H.265/HEVC reference software [7] with following quantization parameters [32, 37, 42, 47]. These result in relatively low bitrates with picture quality ranging roughly from 28 dB to 38 dB. Then, the same test pictures are coded with JPEG, JPEG-XR and JPEG2000 reference softwares so that the decoded PSNR matches the corresponding PSNR of the coded H.265/HEVC picture. The bitrate savings of H.265/HEVC over other standards are then measured using the Bjontegaard-Delta bitrate measure [6].

Medium bitrate range: Above procedure is repeated but using the following quantization parameters for H.265/HEVC [22, 27, 32, 37]. This corresponds to picture qualities that range roughly from 34 dB to 44 dB.

High bitrate range: Same procedure is repeated but using high quality coding, with the following quantization parameters for H.265/HEVC [12, 17, 22, 27]. This

corresponds to picture qualities that range roughly from 40 dB to 50 dB.

Spatial scalable coding: The performance of the draft scalable H.265/HEVC standard (SHVC) is also evaluated for spatial scalability use-cases. For this purpose, Class A and Class B pictures are first downsampled by a factor of 1.5x and 2x. Then the original resolution and its corresponding downsampled version are coded using the draft SHVC standard. The coding efficiency is compared against coding each resolution independently (simulcast) case. In addition, enhancement layer coding efficiency is also compared against coding the high resolution picture as a single layer, to see how much more efficiently the full resolution picture is represented when utilizing the scalability tools. Quantization parameters of 26 and 30 are used for base layer and each base layer is used to code enhancement layer representations with quantization parameters having offsets of -2, 0, +2 and +4 with respect to the base layer quantizer.

4. EXPERIMENTAL RESULTS

4.1. Coding efficiency results

In this section, the objective coding efficiency results of the experiments are analyzed in detail. As more than 800 encodings are performed, it is not feasible to present the results of each test separately. Instead, the summary results are presented as follows. First, the additional average bitrate increase each codec requires to achieve the same objective quality as H.265/HEVC for the low/medium and high bitrate range experiments are presented in Table 2, Table 3 and Table 4. Several observations can be made:

- Improvement H.265/HEVC brings over other still picture formats is larger at high resolutions.
- The improvement H.265/HEVC brings over other still picture formats is larger at low bitrates, compared to higher bitrates. This is also illustrated in Figure 2, where the additional bitrate needed for different codecs over H.265/HEVC are shown for three different bitrate ranges.
- When all the results are averaged, it takes around 2.2X more bits to code same picture with JPEG, 1.5X more bits to code the same picture with JPEG-XR and 1.8X more bits to code the same picture with JPEG-2000. H.265/HEVC provides similar lossless coding capability compared to JPEG-XR but better than JPEG-2000.
- H.265/HEVC brings significantly higher gains for Class-F where computer generated content is present. This is attributed to capability of bypassing transform coding and sample adaptive offset tools, providing significant improvement for that category of content. Results shown in the next section indicate significant gains in visual quality for this content as well.

Table 2 Additional bitrate needed by JPEG, JPEG-XR, JPEG2000 to reach same quality of H.265/HEVC (low bitrate range)

Class	JPEG	JPEG-XR	JPEG-2000
Class A	123.1%	61.5%	38.3%
Class B	177.9%	75.8%	4.1%
Class C	135.2%	62.4%	48.7%
Class D	122.2%	53.6%	41.6%
Class E	218.6%	90.0%	19.8%
Class F	224.6%	101.3%	59.5%

Table 3 Additional bitrate needed by JPEG, JPEG-XR, JPEG2000 to reach same quality of H.265/HEVC (medium bitrate range)

Class	JPEG	JPEG-XR	JPEG-2000
Class A	87.1%	43.8%	47.5%
Class B	123.6%	62.2%	14.7%
Class C	121.7%	52.6%	50.2%
Class D	109.6%	47.1%	42.6%
Class E	169.5%	73.0%	23.4%
Class F	222.7%	117.7%	86.8%

Table 4 Additional bitrate needed by JPEG, JPEG-XR, JPEG2000 to reach same quality of H.265/HEVC (high bitrate range)

Class	JPEG	JPEG-XR	JPEG-2000
Class A	69.2%	29.2%	39.9%
Class B	67.0%	39.1%	11.7%
Class C	74.8%	34.3%	39.4%
Class D	69.6%	32.9%	33.6%
Class E	105.9%	46.7%	4.2%
Class F	198.0%	103.4%	81.7%

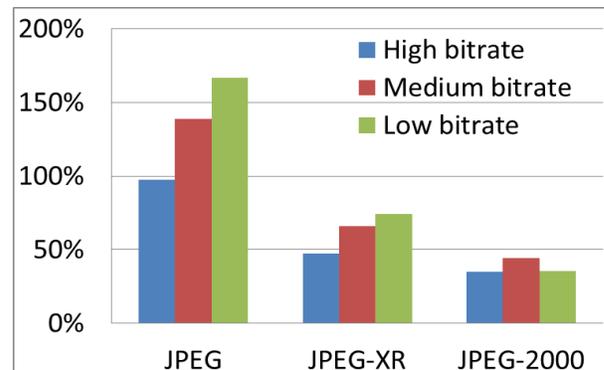


Figure 2 Additional rate required by JPEG, JPEG-XR and JPEG-2000 to achieve the same objective quality as H.265/HEVC for different bitrate ranges.

4.2. Visual results

In order to demonstrate the performance of H.265/HEVC on visual quality, some examples are provided. First, a cropped area from the 1080p sequence Kimono is shown for H.265/HEVC, JPEG and JPEG-XR coded at the same rate

of 0.22 bits per pixel (bpp) in Figure 3. This test picture is useful to demonstrate the performance of different codecs in coding smooth areas. As it can be seen in Figure 3, H.265/HEVC provides significantly higher quality than JPEG and JPEG-XR, where obvious blocking artifacts are clearly visible. Secondly, a cropped area from a computer generated Class-F sequence is shown for different codecs coded at the same rate of 0.89 bpp as shown in Figure 4. This sequence demonstrates the benefits of H.265/HEVC in coding computer generated content as both ringing and blocking artifacts are clearly reduced compared to JPEG and JPEG-XR. The superiority of H.265/HEVC is mostly due to being able to code the residual samples at spatial domain by skipping transform coding.

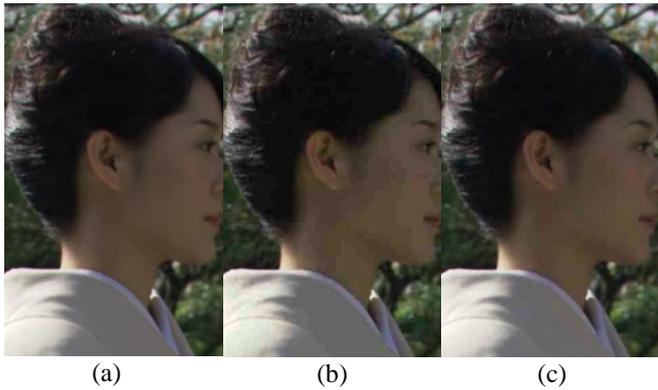


Figure 3 Visual quality of Kimono test picture for (a) H.265/ HEVC, (b) JPEG and (c) JPEG-XR at 0.22 bpp

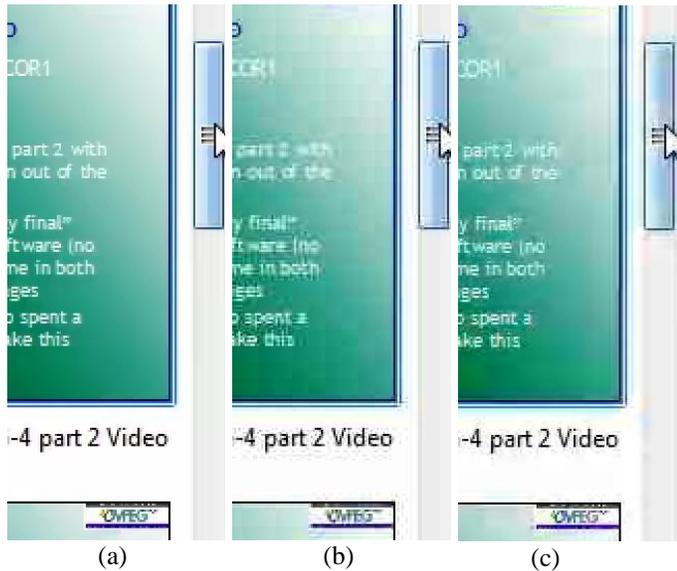


Figure 4 Visual quality of SlideEditing test picture for (a) H.265/ HEVC, (b) JPEG and (c) JPEG-XR coded at 0.89 bpp

4.3. Spatial scalability results

Coding efficiency results for 2x and 1.5x spatial scalability are provided in Table 5. Bjontegaard-delta bitrate savings are reported separately for the full resolution pictures (“EL” results comparing enhancement layer of the scalable representation to the full resolution simulcast coding) and for the combination of the low and full resolution pictures (“EL+BL” results). Results indicate that scalable H.265/HEVC achieves significant bitrate savings compared to simulcast approach. Considering the total bitrate of the low and full resolution representations the average bitrate savings for 2x and 1.5x spatial scalability for this test set are 22.8% and 32.6%, respectively. Considering only the bitrate consumed by the full resolution representation, bitrate savings up to 73.4% are observed.

Table 5 Summary of the coding efficiency result for 2x and 1.5x spatial scalability

Sequence	2x spatial		1.5x spatial	
	EL+BL	EL	EL+BL	EL
Traffic	-25.9%	-40.1%	N/A	N/A
PeopleOnStreet	-28.1%	-44.4%	N/A	N/A
Kimono	-30.9%	-49.1%	-39.2%	-73.4%
ParkScene	-23.2%	-34.2%	-35.3%	-63.3%
Cactus	-21.1%	-31.7%	-33.7%	-60.6%
BasketballDrive	-17.3%	-25.9%	-28.9%	-50.6%
BQTerrace	-12.8%	-17.8%	-25.7%	-42.4%
Best case	-30.9%	-49.1%	-39.2%	-73.4%
Average	-22.8%	-34.8%	-32.6%	-58.1%

5. CONCLUSIONS

H.265/HEVC video coding standard was recently finalized by JCT-VC and it provides significant gains in visual quality over earlier standards. In addition, H.265/HEVC includes a profile designated for coding still pictures. The “Main Still Picture” profile re-uses the same intra coding tools present in H.265/HEVC video profiles, which means the same decoder can be conveniently used to decode the both video and still pictures. Because of this synergy and its high coding efficiency, H.265/HEVC will find significant use in coding still pictures. In this paper the still picture coding performance of H.265/HEVC is analyzed and compared to other still picture codecs, such as JPEG, JPEG-XR and JPEG2000. This is done by running extensive simulations at various bitrates for all the codecs and comparing the results. When all the results are averaged, it is shown that JPEG uses 2.3 times more bits, JPEG-XR uses 1.6 times more bits and JPEG-2000 uses 1.4 times more bits than H.265/HEVC for coding still pictures at aligned objective quality. It is also observed that the improvement H.265/HEVC brings is larger at high resolutions and at lower bitrates, compared to lower resolutions and high bitrates.

11. REFERENCES

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