Performance Analysis of Emerging High Efficiency Video Coding (HEVC)

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Abstract: High definition video is becoming popular day by day due to desire for superior level quality and high resolution video. The upcoming High Efficiency Video Coding (HEVC) standard is designed to serve diverse range of applications like HDTV, video conferencing, fast internet streaming and videophone. This paper describes the performance analysis of HEVC with H.264/AVC video coding standard. Various 1920x1080 resolution high definition sequences are used to check the efficiency of HEVC. Simulation results show that HEVC in comparison to H.264 results in 52 % (average) bit rate improvement without significantly affecting the subjective and objective quality of video.
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1. Introduction

The ongoing demand for efficient video coding to achieve low bit rate and high video quality is growing due to increasing popularity of high definition TV, the delivery of video on mobile devices, camcorders, digital cinema, home cinema, internet streaming, medical imaging, mobile streaming, broadcast and communications, videoconferencing, videophone, telepresence, remote video surveillance, wireless display and other multimedia applications [1]. The basic purpose of the video coding standard is to increase the coding efficiency without compromising on subjective quality of video. Coding efficiency can be increased by two methods. The first method is to decrease the necessary bit rate to represent the contents of the video for a specific level of the video quality, and the second method is to increase the quality of the video contents for a specific bit rate [2]. While high coding efficiency is important for reducing the transmission and storage cost of video, processing speed and area cost also need to be considered in the development of next-generation video coding to handle the demand for higher resolution and frame rates. As a result, new video coding standards are developed to cater this demand. The tremendous growth in video coding standards is mainly fueled by two international organizations: ITU-T and ISO/IEC. The ITU-T produced H.261 and H.263 while ISO/IEC produced MPEG-1and MPEG-4 Visual standards. Moreover, these two organizations also worked jointly and produced the H.262/MPEG-2 and H.264/MPEG-4 AVC standards. The two standards that were jointly produced had a strong impact and have found their usage into a large number of different products that are prevalent in our daily lives. During this growth, valuable efforts have been made to increase the compression capacity and improve other features like robustness of data loss, while considering the practical computational complexity that is used in products at the time of projected operation of each standard [3].

To fulfill the demand of new challenges, the ISO/IEC MPEG and ITU-T VCEG in a partnership known as the Joint Collaborative Team on Video Coding (JCT-VC) launched their new video coding project, High Efficiency Video Coding (HEVC). The main goal of HEVC is to double the compression efficiency as compared to H.264/AVC: video quality level would be same for both standards but the bit rate will be half for HEVC as compared to AVC for the same video content. HEVC uses several new tools for improving coding efficiency, including larger block and transform sizes, additional loop filters, and highly adaptive entropy coding. It is expected that HEVC will fulfill the increasing requirements for the cost effective video coding with respect to providing high quality, the computational complexity, the spatial and temporal resolution, and the bit rate reduction [4]. This paper describes the performance analysis of HEVC standard with its predecessor standard H.264/AVC. The rest of the paper is organized as follows: Section 2 gives overview of the HEVC standard while the simulation setup and results are discussed in section 3. Finally Section 4provides the conclusion.

2. Overview of High Efficiency Video Coding (HEVC) Standard

HEVC is becoming new emerging standard for the video coding as it is more efficient performer in compression rate and relative quality performance then its successor video standards. The block diagram of the HEVC encoder is shown in Figure 1.

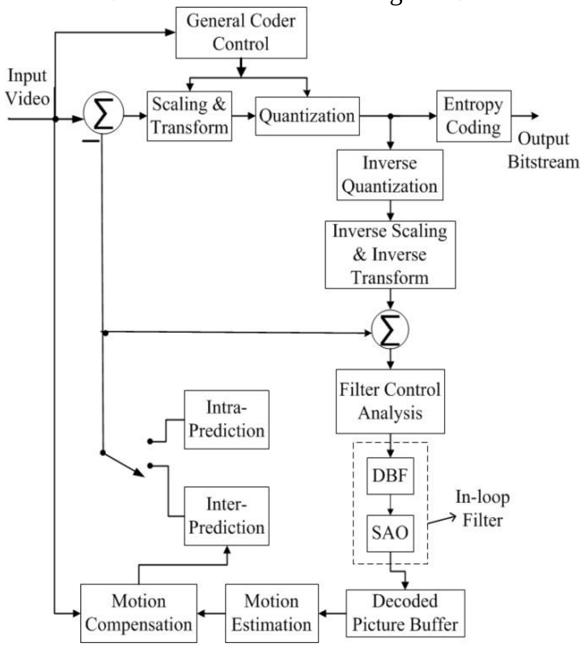

Figure1. Block Diagram of HEVC encoder

In HEVC, the basic approach is to divide the whole image or frame into blocks, apply scaling, transformation and quantization. The coder control block determines the transform parameters and quantization parameter (QP) value. Entropy encoder block convert the quantized coefficients into bit stream. The local decode in encoder does inverse quantization and inverse transform to produce the reconstructed image, which is used as a reference for the prediction of incoming frames of video. Two filters: Deblocking filter (DBF) and Sample Adaptive Offset filter (SAO) are used to suppress the blocking artifacts produced during encoding process. After this, motion estimation and compensation modules are used for intra or inter prediction. The basic building blocks of HEVC are same as that of previous H.264/AVC standard, however there are some significant differences which are explained as follows:

Partitioning: The image is portioned into different blocks as of previous coding standards. However, HEVC has larger block structures with more flexible sub partitioning which makes it more favorable to achieve higher compression rate. The basic building block is called larger coding unit (LCU) divided into smaller coding units (CU), which further splits into smaller prediction units(PU) and finally that PU splits into transform units(TU) as shown in Figure 2.

One more difference is that the maximum block size has been increased to 64 x 64 from 32 x 32 of previous coding standards [3].

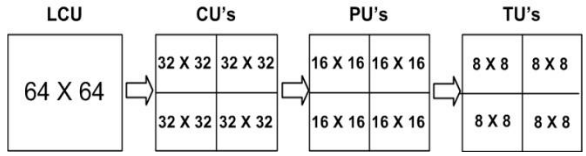

Figure 2. An example of partitioning of 64 X 64 LCU into CU, PU and TU's

Transform and Quantization: HEVC employs DCT to generate coefficient, which are used for quantization process. The maximum range of transform in HEVC is increased up to 32 X 32, whereas, in previous standards, its maximum range was 16 X 16 [5]. The quantization range is also enhanced from 0-51.

Entropy Encoding: HEVC use content adaptive binary arithmetic coding (CABAC) as base entropy encoder whereas, both CAVLC and CABAC were used in H.264/AVC. The use of CABAC in HEVC has improved throughput and compression performance at the cost of increase in coding complexity [6].

In-Loop Filter: In-loop filter is used in HEVC to remove the blocking and ringing artifacts which are introduced during coarse quantization to achieve high compression ratio. There were three loop filters introduced named as DBF, SAO filter and Adaptive Loop filter (ALF). Later on, ALF was dropped from HEVC in order to decrease the coding complexity [7]. DBF works on the boundaries of different partitioning blocks i.e. PU, CU, TU etc. DBF can be turned on or off on the basis of threshold computed through QP ranges defined in standard. SAO classifies and groups the image into different categories and then assign them some particular offset. This offset is assigned on each category in a region to reduce distortion on the basis of either band offset (BO) or edge offset (EO) [8].

3. Simulation Environment and Results

We have used the random access configuration of HEVC encoder because it provides best bitrate improvement with relative comparable subjective quality among other configurations. The HD test sequences used in analysis are all in YUV 4:2:0 subsampling ratio with 1920 x 1080 resolutions. The test sequences consist of BASKETBALL DRIVE, BLUE SKY, CACTUS, PEDESTRIAN AREA, SUNFLOWER and TRACTOR [9]. The sequences used for analysis have various levels of motion ranging from slow, moderate to fast moving objects. For the generation of the rate points, 50 frames of each video sequence at frame rate of 25fps is encoded with four different values of QP chosen as 23, 28, 33 and 38. JM reference software version 18.4 for H.264 while and while HM version 9.2 of HEVC is used for performance evaluation. The other parameters used for analysis are elaborated in Table 1.

Table 1. Various parameters for performance analysis

Parameter	H.264	HEVC
Encoded frames	50	50
Frame rate	25 fps	25 fps
Search range	32	32
Number of reference frame	4	4
Filter	DBF	DBF+SAO
Frame skip	0	0
Entropy encoder	CABAC	CABAC
Intra Period	1st frame only	1st frame only

Table 2 shows the bitrate comparison of HEVC with H.264 for various test sequences. Minus (-) sign is showing the improvement in bitrate of HEVC relative to H.264/AVC.

Table 2. Bit-Rate comparison H.264 VS HEVC

Test Sequences	QP	Bit-Rate (Kbps)		Bitrate Saving (%age)
		H.264	HEVC	
Pedestrian Area	38	1221.56	565.83	- 53.68
	33	2232.77	1001.35	- 55.15
	28	4316.77	1893.68	- 56.13
	23	9185.56	3888.20	- 57.67
Tractor	38	1873.04	1021.14	- 45.48
	33	3767.30	1911.02	- 49.28
	28	8277.08	3976.40	- 51.96
	23	20828.21	8915.00	- 57.20
Cactus	38	1316.96	757.25	- 42.50
	33	2601.04	1446.44	- 44.39
	28	5848.43	2953.84	- 49.49
	23	20927.02	8081.11	- 61.38
Sunflower	38	515.04	303.55	- 41.07
	33	1013.88	523.28	- 48.39
	28	2083.68	1003.65	- 51.83
	23	4569.49	2083.34	- 54.41
Basket Ball Drive	38	1332.61	605.65	- 54.55
	33	2528.58	1099.84	- 56.50
	28	5370.56	2200.39	- 59.02
	23	14736.52	5421.24	- 63.21
Blue sky	38	1137.60	579.19	-49.09
	33	1946.62	984.62	-49.42
	28	3051.20	1782.78	-41.57
	23	6882.81	3491.09	-49.28

It is observed that as the QP is increasing the bitrate is decreasing; this is because for larger QP range larger sample is taken in the image to perform compression. The sequences having fast moving objects take more time and more bitrate to encode as compared to those sequences in which objects are still or moving slowly. Bitrate improvement range varies from 41% to 70% with an average improvement of bitrate of 52%.

Table 3 shows the Y-PSNR comparison of encoded test sequences for the HEVC and H.264/AVC video standards. Plus (+) sign indicates improvement in PSNR of HEVC form H.264/AVC, whereas minus (-) sign indicates that PSNR of H.264 is greater than HEVC.

Table 3. Y-PSNR comparison of H.264 with HEVC

Test Sequences	QP	Y-PSNR (dB)		Difference (dB)
		H.264	HEVC	
Pedestrian Area	38	35.567	35.350	- 0.217
	33	38.226	37.720	-0.506
	28	40.499	39.937	- 0.562
	23	42.295	41.782	- 0.513
Tractor	38	32.462	32.947	+0.485
	33	35.592	35.407	- 0.185
	28	38.667	37.882	- 0.785
	23	41.633	40.354	- 1.279
Cactus	38	31.654	32.160	+0.506
	33	34.343	34.393	+0.050
	28	36.689	36.377	- 0.312
	23	38.958	38.054	- 0.904
Sunflower	38	36.225	37.874	+1.649
	33	39.259	40.254	+0.995
	28	41.891	42.384	+0.493
	23	43.854	44.048	+0.194
Basket Ball Drive	38	34.084	34.242	+0.158
	33	36.313	36.186	- 0.127
	28	38.168	37.944	- 0.224
	23	39.976	39.352	- 0.624
Blue sky	38	34.215	35.404	+1.189
	33	37.702	38.200	+0.498
	28	40.857	40.795	- 0.062
	23	43.290	42.941	- 0.349

It is obvious from Table 3 that PSNR of HEVC does not vary significantly in comparison to H.264/AVC, which indicates that quality of HEVC is almost same as that of H.264 with additional benefit of more than 50% bitrate savings. HEVC shows higher improvement for higher QP ranges generally when it exceeds than 35. For fast moving test sequences HEVC shows slightly less improvement as in PEDESTRIAN AREA, BASKETBALL DRIVE and TRACTOR, whereas for slow moving it shows significant improved results. Figure 3 shows the bitrate saving relative to average PSNR for various test sequences.

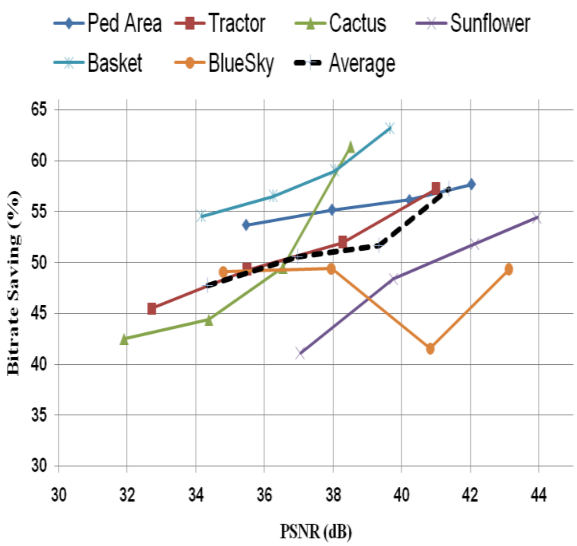

Figure 3. Bitrate saving relative to average PSNR of HEVC and H.264

In Figure 3, for each QP value, corresponding PSNR of HEVC and H.264 are averaged together and plotted against the corresponding bitrate saving. Similarly, rest of data is plotted for other QP values given in Table 2 and Table 3. The dashed black line indicates the overall bitrate saving. It is apparent from Figure 3 that average bitrate saving for all test sequences is about 52%.

4. Conclusion

We have performed performance analysis of HEVC with H.264 using various high definition sequences. Experimental results show that HEVC achieves an average of 52% bit rate saving in comparison of H.264 with same subjective and objective quality of video. It is also observed that HEVC performs better for higher QP ranges by giving higher PSNR and bit rate savings.

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