A COMPARATIVE ANALYSIS BETWEEN DIRAC, H.264 AND HEVC VIDEO ENCODERS AT VARIABLE BIT RATES

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Abstract: *This work presents a comparative analysis of Dirac, H.264 and HEVC video codecs. Encoding file sizes, Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Metric (SSIM) measurements and encoding times are compared. Akiyo, Stefan and Caesar video sequences are used for comparisons. This work enhances previous studies on the performance comparison of the three codecs, by providing comparison results at Variable Bit Rates (VBR).*
Keywords: Dirac, H.264, HEVC, CBR,VBR.

1. Introduction

The explosive growth of video applications such as video on demand and internet video broadcasting increase the need for storage space and bandwidth. Moreover, recent developments in video recording and display technologies energized the presence of high definition (HD) content in digital video communication. To meet these demands, video codec research communities design new algorithms which are able to significantly improve the compression performance of the state-of-the-art H.264 [1].

Dirac is an open and royalty-free video codec provided by the BBC [2]. Its main goal is to realize higher quality and more efficient video compression from standard web streams up to HD and it competes with existing technologies such as the H.264 and the Windows Media Video (WMV). Furthermore, Dirac aims to outperform the High Quality Video Codec (HEVC) in multiple performance metrics such as encoding and decoding times, SSIM performance.

HEVC is jointly developed by the Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG), working together in the Joint Collaborative Team on Video Coding (JCT-VC) [1]. Like Dirac, the main goal of the HEVC is to obtain significantly improved compression performance with regard to H.264 [1,3].

Codecs' performance is evaluated by utilizing PSNR and SSIM in this paper. PSNR is the best known quality metric but has some drawbacks regarding perceptual quality. It doesn't consider contrast and luminance arguments but SSIM calculates this information for a given image. Moreover, Dirac also has a special metric called the quality metric (QM) that has a higher sensitivity than PSNR for the human eye, and SSIM bears resemblance to QM in many regards. At the end, encoding time comparison between the three codecs specifies computational burden.

This paper is organized as follows. Section 2 reviews H.264, Dirac and HEVC. Section 3 presents compression ratios of some test video streams are presented at Variable Bit Rates (VBR). PSNR, SSIM and computational time results are also given for a comprehensive comparative analysis in Section 3. Section 4 concludes this paper.

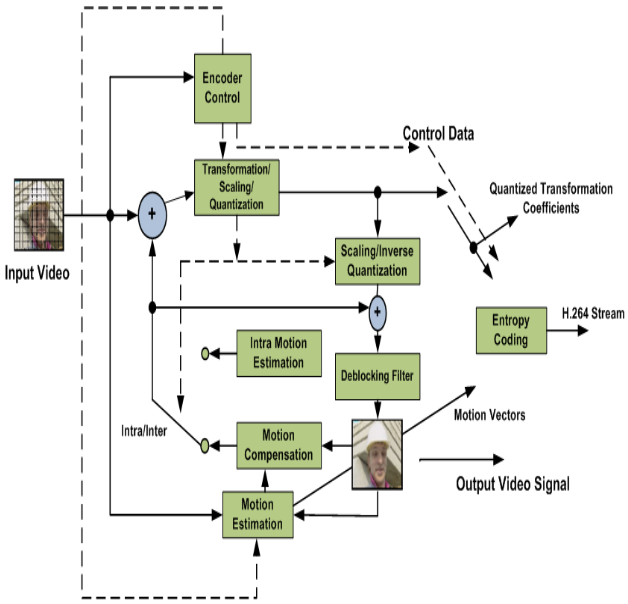

Figure 1. H.264's encoder architecture [4]

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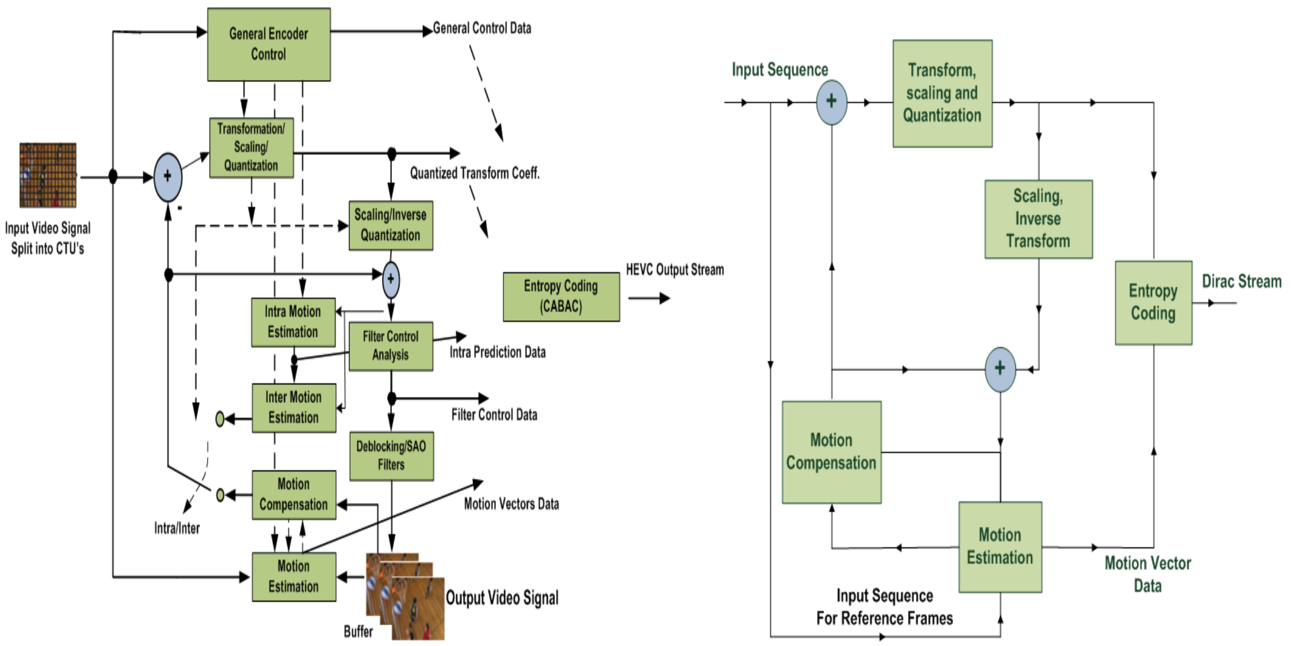

Figure 2. HEVC and Dirac architectures (Left HEVC, right Dirac) [1,3]

2. H.264, DIRAC and HEVC

The following subsections briefly describe the important aspects of these encoders.

2.1. H.264

H.264 is the most widely used video codec. It is block-oriented and hybrid motion estimation based codec, which is developed by JCT-VC [4,5]. The standard was developed in 2003 and contains a number of features that allow it to compress input video stream much more effectively than older encoders. On the other hand, complex structure of this codec and enormous cost in license fees are important drawbacks. H.264 is based on Discrete Cosine Transform (DCT) and it lacks the time-frequency localization flexibility of Discrete Wavelet Transform (DWT). However, H.264 is more developed codec than Dirac, providing better results about compression efficiency at CBR [6]. At VBR, the same conclusion cannot be drawn.

2.2. Dirac

In the Dirac video codec, image motion information is extracted to predict next frames. Temporal and spatial redundancies are removed by hybrid motion estimation and discrete wavelet transform. The block diagram of Dirac can be seen in Figure.2. Discrete Wavelet Transform (DWT) removes dependencies among individual frames by using lifting [2,4,5]. Wavelet lifting packs most of the picture information into a few sub-bands. This process can achieve higher levels of compression. Wavelet lifting brings computational efficiency over conventional wavelet and discrete cosine transforms. Wavelet base selection has an important impact on compression performance. Base selection also affects encoding and decoding speeds.

In Dirac, dead-zone quantized and scaled transformation coefficients are sent to entropy coding block [2,6]. Entropy coding is applied in three stages: binarization, context modeling and arithmetic coding [2,6,7]. The main idea of the first stage is to generate a modified bit stream. The context modeling is based on parent-child organization [8]. Finally, arithmetic coding performs lossless compression depending on local statistical features of input frames. Dirac consists of comparatively simpler main blocks than H.264 and HEVC.

2.2. HEVC

The main goal of this video is to realize significantly better compression performance than other codecs in the range of 50% bit rate reduction, for the same perceptual video quality [1]. HEVC focuses on video resolution and increased use of parallel processing.

HEVC hybrid video coding is based on Coding Tree Units (CTUs) in this codec as shown in Figure.2. These structures consist of Coding Blocks (CBs), Prediction Blocks (PBs) and Transformation Blocks (TBs) [1,2]. This hierarchical concept brings much more flexibility than the older H.26L codecs. In transformation block, the discrete cosine can be defined down to 4x4 pixels depending on input stream and user’s signaling description. Moreover, for the 4x4 transform of intra picture prediction, the discrete sine transform is specified as an alternative integer process. In addition, advanced motion vector prediction and asymmetric motion partitioning approaches are improvements unique to HEVC [1,3].

The wave-front parallel processing accelerates encoding of source stream by dividing into slices and tiles. Multi-directional operation of intra-picture prediction between 0 and 34 gives additional compression performance while keeping perceptual quality at CBR and VBR [1].

3. Experimental Results

We use the reference software of Dirac (the latest version of pure Dirac is 1.0.2), H.264 (JM18.5) and HEVC (HM 11.0) respectively [9,10,11]. Akiyo, Stefan and Caesar test video clips are used with QCIF, CIF and VGA (640x400) resolutions respectively. 30f/s and 40f/s frame rates are used for performance comparison. All reference software is fully implemented in the C/C++ programming languages. These codes are executed by 64-bit Intel i5 processor, running at 2.4GHz.

Encoding conFigureurations are as follows: The Rate Distortion Optimization (RDO) mode and loop-filter are enabled in H.264 main profile and HEVC encoder intra main of 8bits. In H.264, HEVC and Dirac, fast full search mechanisms are activated. Motion vector accuracy was specified as 1/8 in Dirac. Quality Parameter (QP) values of these codecs are 7, 28 and 32 respectively. Moreover, Dirac wavelet organization is structured by using Deslauriers-Dubuc 13/7 interpolation lifting filter as a default concept [12]. Most of these settings are typical settings for the respective codec. The simulation results are analyzed in three aspects: PSNR, SSIM (by using [13]'s environment) and encoding time at VBR.

Dirac has the best performance in objective quality assessments (PSNR, SSIM), however it has a worse Compression Ratio (CR) as shown in Figure.4 and Table 1. HEVC provides the best compression ratio. However, if the compressed file size is not very critical, Dirac may be a good no-cost selection.

As investigated in Figure.5, Dirac's simplicity significantly outperforms HEVC and H.264 regarding computational in encoding speed.

Figure 3. Test video clips (Upper-left Akiyo (50 frames @30Hz), upper-right Stefan (90 frames @30Hz), lower Caesar (101 frames @40Hz)) [14]

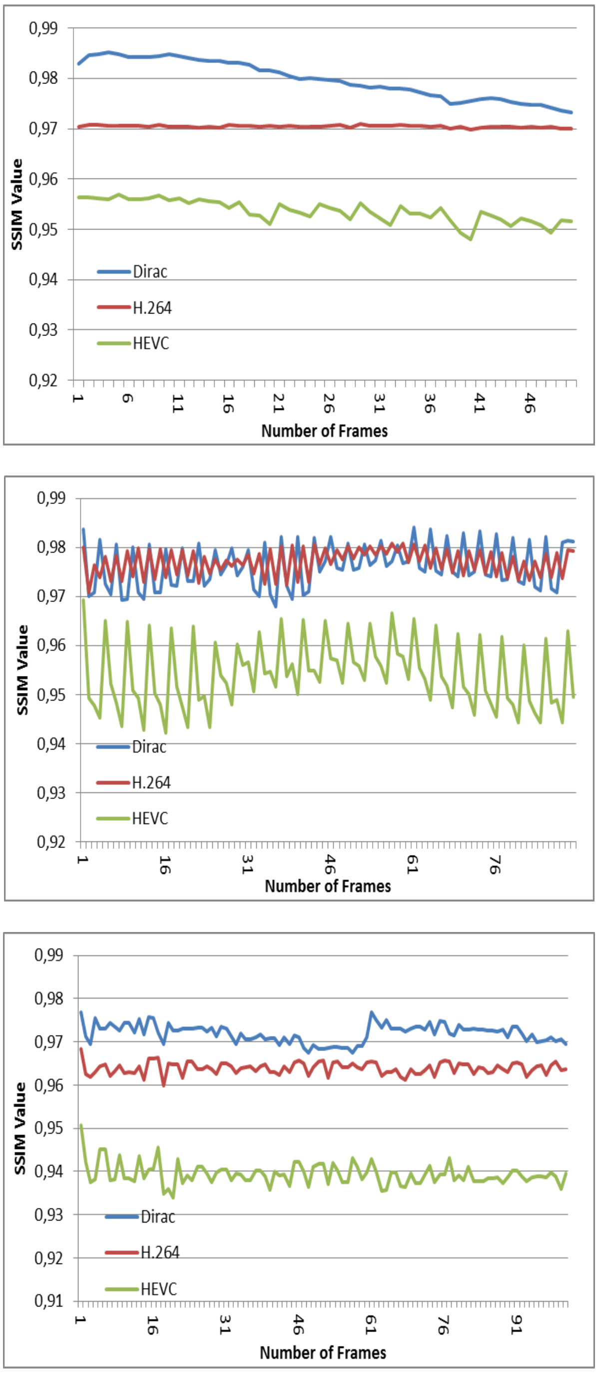

Figure 4. SSIM performance comparison at VBR (Upper Akiyo, center Stefan, lower Caesar)

Dirac entropy coding used in this paper is achieved by replacing the original Dirac arithmetic coder with an accurately conFigureured M-coder [15]. The new scheme is three times faster for high bit rates. Furthermore, H.264 and HEVC have more complex entropy coding approaches, consisting Context Adaptive Binary Arithmetic Coding (CABAC) and header formatting layers. Moreover, the reference software of these codecs is non-optimized. However, the speed rankings among the three codecs do not change, due to the fact that the optimized performance can only be up to three times faster than the non-optimized performance [1,2,3].

Table 1. Overall performance comparison for three codecs

Source Stream	Video Codecs	SSIM (Mean)	PSNR (Mean-dB)	Encoded File Size (KB)	CR (%)
Akiyo	Dirac	**0.979**	**40.6**	127	98.85
	H.264	0.9	38.74	7	99.93
	HEVC	0.953	36.22	**4**	**99.96**
Stefan	Dirac	0.976	35.71	590	95.58
	H.264	**0.977**	**35.85**	341	97.44
	HEVC	0.95	31.7	**110**	**99.17**
Caesar	Dirac	**0.971**	**39.4**	458	98.79
	H.264	0.963	38	165	99.56
	HEVC	0.94	34.75	**56**	**99.85**

4. Conclusions

To enhance previous results on performance comparison between H.264, Dirac and HEVC video codecs at CBR [16], a VBR performance comparison is presented in this work. In addition to PSNR and SSIM, encoding time is included in our analyses.

Using typical quality parameters and the three test cases, the following can be observed: Dirac outperformed H.264 and HEVC in PSNR and SSIM. However, HEVC outperformed H.264 and significantly exceeded Dirac for encoded file size. Dirac had significantly shorter encoding times with respect to H.264 and HEVC. Among the three codecs compared, Dirac is the only open source, royalty free codec.

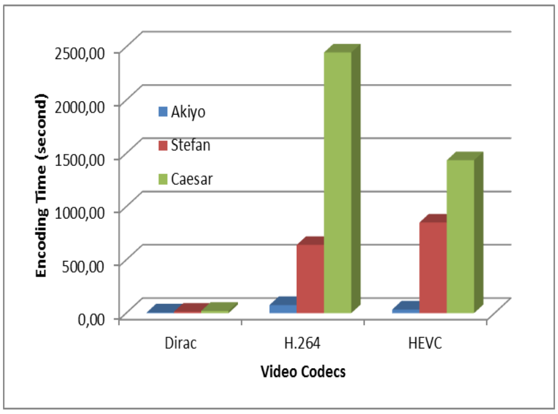

Figure 5. Computational performance comparison

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