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Performance Analysis of Video Coding Schemes with Reference to Intra-Coded High Efficiency Video Coding (HEVC)

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Abstract: Compression efficiency of a video codec is very important to enable it to encode high quality videos at low bitrates while keeping its quality similar to the original video. Significant progress has been made in the area of video encoding. The latest state of the art video encoding standard, High Efficiency Video Coding – HEVC/H.265 doubles the video quality for the same bitrate compared to other codecs. To evaluate the performance efficiency of HEVC, this paper evaluates video quality and computational efficiency performance comparison amongst H.265, H.264 and Motion JPEG. Alongside the need for high compression efficiency, it is also important to consider the computational complexity of the video codecs. It is concluded that, although HEVC provides the best compression efficiency, it does so at the expense of significantly more computational cost than H.264. The conducted experiments show that HEVC results in the best PSNR performance of the encoded video sequence followed by H.264. However, in terms of coding efficiency Motion JPEG while employing its Kakadu implementation resulted in fastest encoding times followed by HEVC. Videos encoded with Motion JPEG using OpenJPEG library produced the worst PSNR performance. H.264 resulted in the worst computational efficiency and the produced video quality performance was comparable to that of Motion JPEG. This work is meant to provide insights regarding the performance comparison of the video encoding suites and future developments of the codecs.

Keywords: Analysis of Video Coding Schemes High Efficiency Video Coding – HEVC/H

1. INTRODUCTION

Computing power doubles every year according to Moore's law and the devices get cheaper and efficient, however the desire for squeezing every ounce of performance out of the hardware is ever growing. Super computers of the past and the smartphones of today will be the wearables of tomorrow but the limitation comes in terms of power consumption. As the devices get smaller, the capacity of the battery power reduces. The balance between functionality and power consumption can be maintained by efficiently utilizing the system resources (Minkyu *et al.,* 2013). Most of the consumer devices are used as a multimedia gadget, therefore the need for providing visually appealing multimedia content at lowest bitrate and least power consumption is the top priority. In this pursuit, video codecs are always evolving, trying to create the perfect balance between quality and performance. Many codecs have been released, however few of them managed to acquire the attention in existing multimedia market. H.264/AVC is the most famous among them. HEVC is the successor to H.264/MPEG-4 AVC (Advanced Video Coding) (Ohm *et al.,* 2012).

HEVC is able to double the compression performance compared to H.264, whilst maintaining the same level of video quality. HEVC achieves this by relying upon enhanced intra prediction, de-correlation transforms, de-blocking filters, motion estimation and variable length entropy coding to produce good quality at high compression ratios (Ohm *et al.,* 2012).

Work on developing a codec which can produce substantially good quality videos with high compression ratios and respectable performance was started as early as 2004(ITU-T, Recommendation H.265).With the need of achieving high compression ratios, computational performance of the codec is also of great importance considering the most common usage of these codecs and the targeted devices which have usually very low reserves of battery power to sustain and maintain longer usage of the device. Disinterment of the codec in terms of high compression ratio, higher performance and low power consumption is the main purpose of this paper.

2. VIDEO CODECS AND LIBRARIES

The used selected codecs and their respective software libraries are listed below.

A. HEVC (High Efficiency Video Codec):

HM version 14 was used for the evaluation of HEVC/H.265 intra encoding. We considered Intra Period of 1, max coding unit (Max CU) of 64x64, slice mode of 0 and slice argument of 1500 in our experimental setup(Sullivan *et al.,* 2012). The source code of HM was downloaded from their website and compiled using Microsoft's Visual Studio 2013 with default settings (Zhenzhong *et al.,* 2008).

B. H.264/AVC (Advance Video Codec):

JM version 18.6 was used for the evaluation of H.264/AVC intra and inters coding. We compiled the source code downloaded from JM website using

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Microsoft's Visual Studio 2013 with default settings (Ostermann *et al.,* 2004).

C. Motion JPEG

For Motion JPEG performance evaluation, we utilized the following libraries.

a. KAKADU is a closed source library used for JPEG 2000 images and Motion JPEG video encoding. It is written by David Taubman. It is used in Apple's Quick time player (Li *et al.,* 2009) and implements the ISO/IEC 15444-1 standard. We used it for encoding videos at different rates (Li *et al.*, 2009).

b. **OpenJPEG** is an open source library to encode and decode JPEG 2000 images and Motion JPEG videos. It was forked from libj2k which is another open source JPEG 2000 library written by David Janssens (Wei *et al.*, 2006).

3. SIMULATION ENVOIRNMENT

In our experimental setup, we have utilized the following environment. In order to have performance evaluation and comparison, all the tests were conducted on the same simulation environment, with specifications listed in **(Table 1).**

Table 1: Systems Parameters

OS	Windows 7 Home Premium (64bit)
Processor	Intel Core i7 2670qm
Cores	4 Physical
Threads/Core	8
Frequency	2.2GHz
Turbo Boost	Disabled
RAM	8 GB DDR3
HDD speed	5200 RPM

4. EXPERIMENTAL RESULTS

In our experimental setup, we evaluated the compression performance of HEVC intra encoding, H.264 intra, H.264 inter and Motion JPEG 2000. For MJ2K we used 2 different popular libraries; Kakadu, which is a closed source library used in several popular softwares like Apple's QuickTime and OpenJPEG library, which is an open source library used for JPEG 2000 encoding and decoding. We have encoded 7 full HD (1080p) raw YUV 4:2:0 videos with diverse compression rates. Default settings of Kakadu and OpenJPEG were used to encode MJ2K videos at different compression rates.

H.264 inter encoding was also performed to see how much gain can be achieved in terms of video quality and performance in comparison with HEVC intra encoded videos. The results achieved from the tests showed that HEVC intra encoding outperformed H.264 inter encoding in achieving high compression ratios, good output quality and high computing performance. MJ2K encoded video using Kakadu produced better quality videos then H.264 intra encoding and often those results were comparable to H.264 inter coding. However Kakadu took the least amount of time in encoding a video among the mentioned batch of encoding softwares. OpenJPEG encoded MJ2K videos produced the worst quality videos for the same range of compression rate. For comprehensibility, 24 or 25 frames of each sequence were encoded with compression ratio range of ~20mbps to ~30mbps.Details of the video sequences used for the experiments are listed in the **(Table 2).**

Table 2. Used Video Sequences

Sequence Name	Resolution	Frame Rate
Tennis	1920x1080	24
Station	1920x1080	25
Rush Hour	1920x1080	25
Riverbed	1920x1080	24
Pedestrian	1920x1080	25
Kimono	1920x1080	24
BlueSky	1920x1080	25

The PSNR versus Bitrate performance of the used video codecs for the considered video sequence listed in Table 2 is given in the figures below.

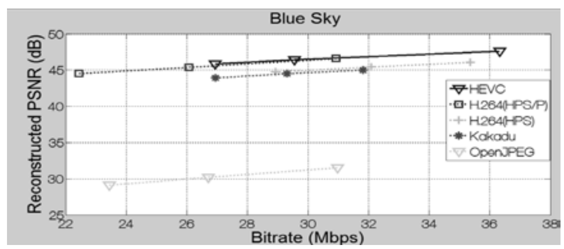

Fig. 1: PSNR versus Bitrate Performance of Blue Sky Video Sequence

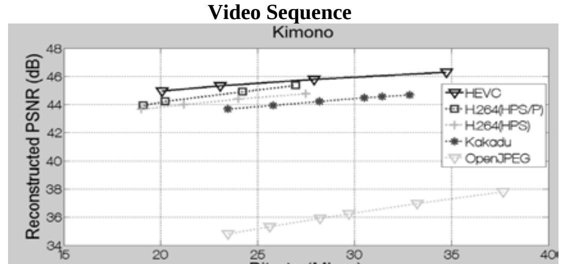

Fig- 2: PSNR versus Bitrate Performance of Kimono Video Sequence

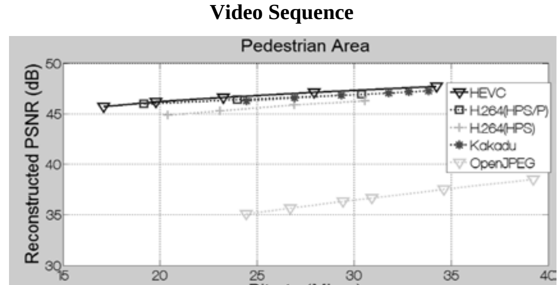

Fig- 3: PSNR versus Bitrate Performance of Pedestrian Video Sequence

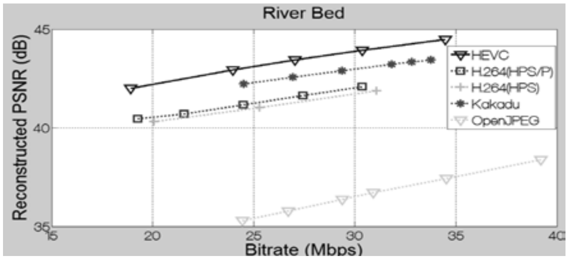

Fig- 4: PSNR versus Bitrate Performance of River Bed Video Sequence

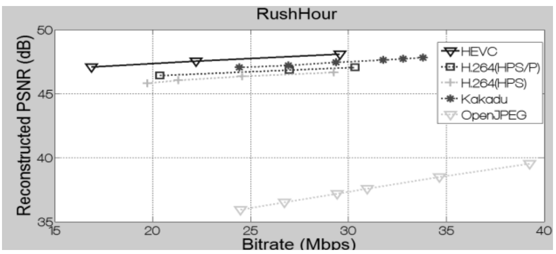

Fig- 5: PSNR versus Bitrate Performance of RushHour Video Sequence

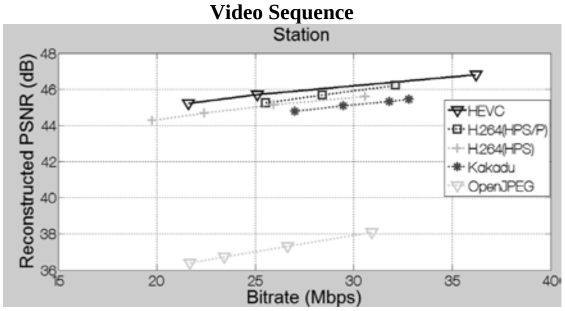

Fig- 6: PSNR versus Bitrate Performance of Station Video Sequence

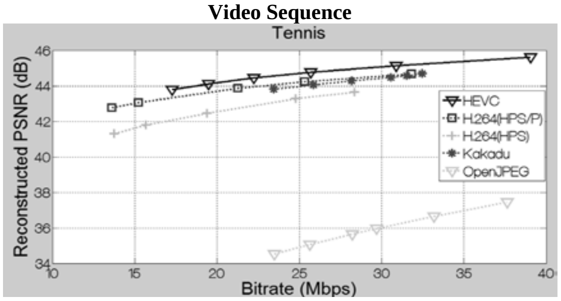

Fig. 7: PSNR versus Bitrate Performance of Tennis Video Sequence

From these graphs we can see HEVC intra encoding often beats both Intra and inter encoding of H.264 in terms of quality for a given bitrate. Motion JPEG 2000 encoding using KAKADU generated videos were almost identical and in some cases better in quality then H.264 inter and much better then H.264 intra. KAKADU managed to yield such quality with much less time complexity and efficient utilization of the hardware then both the configurations of H.264. Open JPEG always produced worst quality video output which often had artefacts and fairly huge amount of noise with way more computational power consumption then KAKADU but faster than HEVC intra and H.264 (intra and inter).

The computational complexity or encoding time for each format and encoding software for a ~26mbps bitrate.

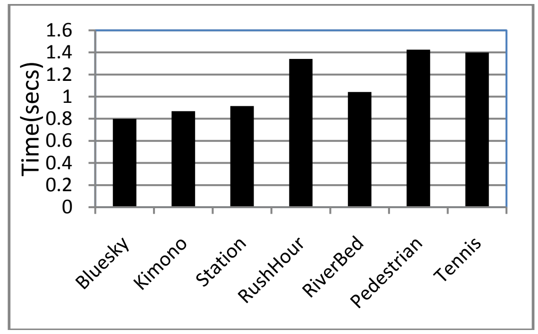

Fig. 8: KAKADU

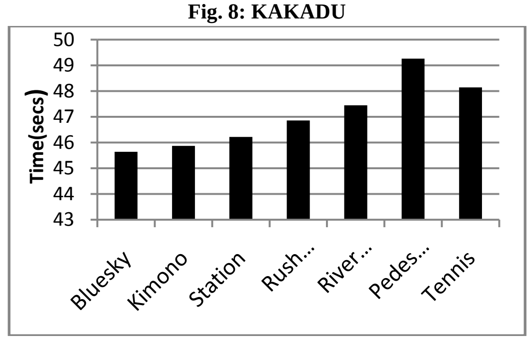

Fig. 9: OpenJPEG

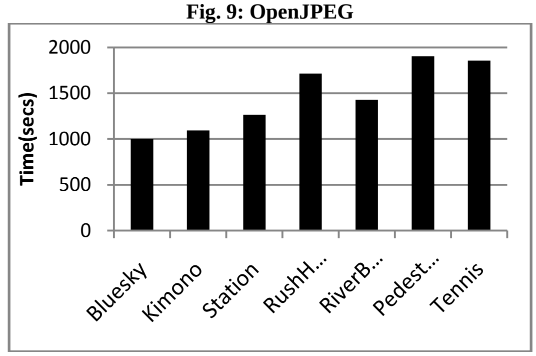

Fig. 10: HEVC

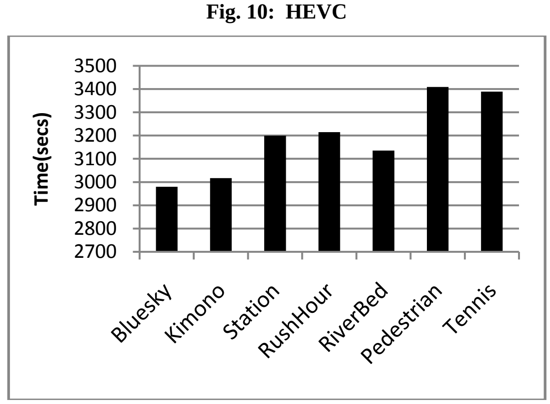

Fig. 11: H.264 Intra

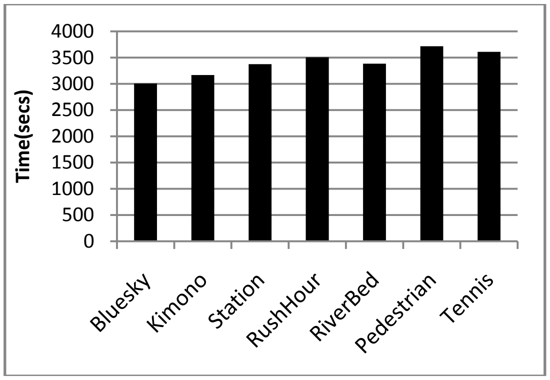

Fig. 12: H.264 Inter

We also measured the computational performance (execution time) of codecs in terms of how much time they took to encode a sequence for a given compression rate. In our performance analysis study, Kakadu (MJ2K) performed the best with the fastest encoding times, followed by OpenJPEG (MJ2K). HEVC came out with 3rd fastest time, H.264 intra came 4th and H.264 inter encoding mostly had the slowest encoding time. Following graph shows the average encoding time taken to encode the mentioned sequence for the provided compression range.

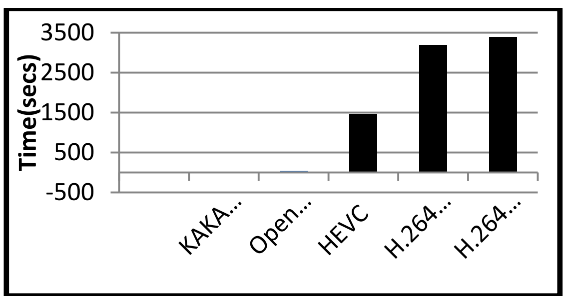

Fig. 13: Average Computational Performance

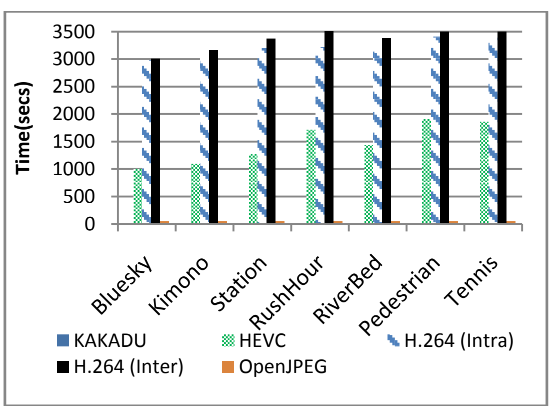

Fig – 14

5. CONCLUSION

The conducted tests results for the quality and performance evaluation of H.264 successor; High Efficiency Video Coding (HEVC), different variants of H.264 and Motion JPEG 2000 show that Kakadu (MJ2K) outperforms HEVC and other encoders in terms of performance, however HEVC (intra) surpassed other codecs for producing best video quality at high compression rates. H.264 inter showed inferior performance in terms of execution time compared to other codecs, whereas OpenJPEG (MJ2K) produced the worst quality videos for a given compression rate.

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