Objective Quality Assessment of Multi-Resolution Video based on H.264/AVC and H.265/HEVC Encoding

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Abstract. This study aims to carry out an objective assessment by evaluating the encoding performance of the new standard compared to its predecessor H.264/AVC. In addition, to produce a comprehensive investigation, we compared several resolutions (1080p, 720p, and 480p) with a combination of CRF and encoder presets. To find out the performance of both techniques we used several test parameters such as encoding duration, compression ratio, bitrate, MSE, and PSNR. The results showed that H.264 was faster in terms of the time needed to carry out the encoding process. However the compression ratio and bitrate of H.265 was better with a difference of 38.5% and 52.7% respectively. Finally, if the user wants to prioritize better quality video output without having to sacrifice a lot of compression time and small file size, then our recommendation is to use H.265 and by HD resolution configuration (720p) with medium presets and 18 CRF value.

Keywords: Objective assessment, Video encoding, H.264/AVC, H.265/HEVC, CRF, Encoder preset

1 Introduction

With the rapid development of internet technology, humans are inseparable from the need to access digital multimedia such as images, audio or video. Nevertheless, video is one of the most popular types of multimedia consumed by the public in recent years [1]. Reported from [2], currently around 75% of data transmission over the world-wide network is video content. This number continues to grow and is predicted to increase more significantly from year to year. To meet users needs for higher (better) resolution and quality, service providers must strive to improve the quality of presented video and display technology along with encoding and transmission standards.

Based on the study several years ago study until now, the assessment of audio and video quality is still an interesting issue and continues to evolve [3]. Based on this trend, the video encoding technique is the most often topic discussed in the research community and broadcasting experts. This is because the evolution or development of video standards, in theory, should align and can be implemented in a certain technology. Moreover, digital broadcasting companies have started to present UHD content on digital TV channels [4]. This

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triggers an increasing need for video compression. Thus, one of the most critical needs in the realm of video coding is to increase efficiency at lower costs [5].

Today, several techniques or methods related to video coding have emerged. Some of the most known and popular used are H.261, MPEG-2, MPEG-4, H.264/AVC, H.265/HEVC, VP9, AV1, and so on [1] [5] [6]. Several studies have also been conducted to compare the quality and performance of video encoding techniques. Research conducted by [7] aims to compare the H.264 technique with H.265 for 4K video sequences. The results of this study indicated that the coding speed of H.264 is faster than that of H.265. However, H.265 coding performance is better than H.264 by saving nearly 50% bitrate compared to H.264, so H.265 is more suitable for 4K coding. Then research by [8] aims to make a subjective and objective assessment of three video compression techniques, MPEG-2, H.264, and H.265. This study produced a video quality database called the FERIT-RERK database that contains 90 degraded full HD videos produced by three techniques tested. It can be used by who might be interested in the development of video coding. The next research conducted by [3] aims to compare the performance of HEVC with H.264/AVC based on objective assessment. According to the experiment results, the HEVC standard is more suitable for applications with low bitrates and has low-delay communication.

There are many video encoding techniques available, but H.264/AVC [9] and H.265/HEVC [10] are the two latest video encoding standards developed by the Video Coding Experts Group (VCEG) and ISO/IEC Moving Picture Experts Group (MPEG). H.264 is considered a mature standard [11] and is widely used for various applications both real-time and non-real-time [12] [13]. Whereas H.265 is an evolution of its predecessor with the target of 50% bitrate saving but has similar quality encoding results [5] [8].

Although many studies focus on objective quality assessment [3] [5] [8] [14] [15] [16] [17], only a few of them carried out an analysis of the quality defined by CRF values [18] and encoder presets [11]. With the number of adjustable parameters that can be configured, H.264 and H.265 implementations have choices in determining the CRF value and encoding presets. CRF represents the type or variation of compression parameters, which determine the quality level of a video [14]. The best video quality perceptual can be obtained by controlling or adjusting quantization levels indirectly using CRF. However, CRF does not have direct control over the actual bitrate used for transcoding video segments. It causes the configuration of the same CRF parameters will generate diverse bitrates when applied to different videos or even different segments in a single video [19]. The selection of certain encoder presets is actually to adjust some internal parameters, such as a number of B-frames, recursion, Coding Tree Unit (CTU) size, lookahead, etc. Although the selection of slower presets by using fix bitrate produces better video quality compared to the use of faster presets, this condition does not always meet [11]. Based on this, if we know the performance for each CRF value setting and preset, we will be able to choose for specific applications effectively. Therefore, this study aims to investigate the performance of H.264/AVC and H.265/HEVC based on a combination of CRF values and preset encoders for various resolutions, 1080p, 720p, and 480p. Then to find out the performance of both techniques, we used several testing parameters, such as encoding duration, compression ratio, bitrate, MSE, and PSNR.

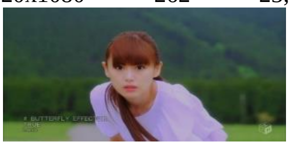
2 Experiment Setup

This section describes the configuration of the selected video source, the test environment includes the hardware and software used, the selection of CRF values and encoder presets, performance testing parameters, assessment scenario.

2.1 Video Source Selection

To obtain comprehensive analysis results, we used three raw videos with 1080p resolution which will be encoded using both techniques that are compared. These videos consist of a video camera (Game Changer), 2D animation (Butterfly Effector), and 3D animation (Chika Dance) that described in **Table 1**.

Table 1. Selected Source Videos

File Name	Format	Resolution	Duration (s)	FPS	Bitrate (Mb/s)	File Size (MB)
Game Changer.mpg	MPEG-2	1920x1080	160	25	12,9	247
						
Butterfly Effector.ts	MPEG-2	1920x1080	262	23,98	10,6	331
						
Chika Dance.mpg	MPEG-2	1920x1080	97	25	12,9	149
						

2.2 Experiment Environment

We use HandBrake to carry out the encoding process based on both encoding techniques. A handbrake is open-source software that used as transcoders that support several encoding techniques. While our computer specifications equipped during the assessment process are as follows: Windows 7 Home Premium 64-bit operating system, Intel (R) Core (TM) 2 Duo CPU T6400 @ 2.00GHz Processor CPU, and Mobile Intel (R) 4 Series Express Chipset Family graphics card.

2.3 CRF and Presets Selection

CRF and encoder preset can be set in HandBrake. Smaller CRF value will result in a significant increase in the output video size and vice versa. If the CRF value is 0, the resulting video output will be lossless and have a larger size than the video source, unless the source is also lossless. According to [18], in general, the configuration of a reasonable standard CRF value is between 18 and 28. While specifically for the H.264/AVC and H.265/HEVC configurations are 23 and 28 respectively. Based on this, we choose CRF values that are close to these criteria, 18, 23, 28, and 33.

The presets encoder has ten levels of speed, the descending order of the presets is Ultrafast, Superfast, Very fast, Faster, Fast, Medium, Slow, Slower, Very slow, and Placebo. However, [11] stated that the default preset is a medium, while slower to placebo requires a very long encoding time and is not comparable with the quality produced (little enhancement output). Therefore, we chose the highest speed (ultrafast), medium, and slow presets.

2.4 Assessment Parameters

To determine the performance of both techniques, we used several test parameters, such as encoding duration, compression ratio, bitrate, MSE, and PSNR. Encoding duration represents how long it takes for an encoding process based on a certain configuration. The compression ratio is the percentage ratio between the size of the source and output video. Bitrate is related to the quality of the image produced. Usually the more bits for each pixel, the better the picture quality, and vice versa. MSE is a metric estimator of image quality measurement by comparing two images that are defined as equation (1).

$$MSE = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}\left[I_{(x,y)} - I'_{(x,y)}\right]^2 \quad (1)$$

From the above equation, MSE is a representation of the absolute error. Whereas PSNR uses video signals as objective parameters. PSNR compares the signal from each video frame in the video source with each video output frame and measures the difference between them [20]. The ratio of the two videos/images is computed in decibels. PSNR is expressed as equation (2).

$$PSNR = 20log_{10}\left[\frac{255}{\sqrt{MSE}}\right] \quad (2)$$

2.5 Assessment Scenario

The selected video sources will be encoded based on two techniques using HandBrake with various combinations of resolutions, CRF values, and encoders preset. The result of each test parameter obtained from three video sources is then averaged. We use Matlab to analyze MSE and PSNR parameters. But, because Matlab does not support the H.265/HEVC format directly, testing is carried out by first extracting the frame from the source and output video. After that, we used a sample of the same frame from the source and output video to be analyzed.

The initial step in the encoding process using H.264/AVC and H.265/HEVC is dividing the image into 8x8 macroblocks, consisting of Y (luminance), Cb and Cr (color/chrominance) components for the test sample. Each video encoding technique has a different maximum macroblock partition size, where the maximum size of H.264/AVC macroblock is 16x16, while the H.265/HEVC is 64x64. Therefore, as in [21], the size of the macroblock used for the testing process is the minimum macroblock size, which is 8x8. In addition, in this study, we used a single frame sample for each test of three videos.

3 Experimental Results and Discussions

3.1 Encoding Duration

Information about the time required to encode from each test scenario can be seen in **Fig. 1**.

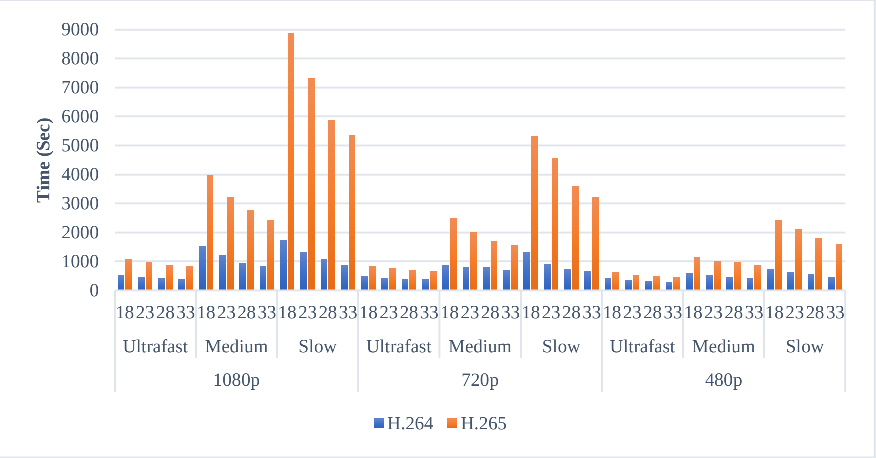


Fig. 1. Encoding Duration of H.264 and H.265

Based on **Fig. 1**. we can see that the slowest encoding process duration (around 2 hours 46 minutes) is H.265/HEVC encoding process with 1080p resolution, slow preset, and 18 values of CRF. While the duration of the fastest encoding process (about almost 5 minutes) is H.264/AVC encoding process with 480p resolution, ultrafast preset, and 33 values of CRF. This caused the overall H.264 technique have faster encoding duration compared to H.265 with a large enough difference which is almost about 27.5 minutes. More than that, the time needed to carry out an encoding process is influenced by several conditions/configurations. The lower the resolution, but with the fastest presets and the greater the CRF value, the faster the encoding process. Based on this, if we want a faster encoding process time, we can consider selecting the output video output with a low resolution, but with the fastest presets and the highest CRF value.

3.2 Compression Ratio

Based on **Fig. 2,** we can see that the highest compression ratio (42,36%) is owned by H.265/HEVC with 480p resolution, ultrafast preset, and a CRF value of 33. While the lowest compression ratio (1,15%) is owned by H.264/AVC with 1080p resolution, ultrafast preset, and CRF value 18. In this case, the lower the target video output resolution, but with the fastest preset and highest CRF value, then the compression ratio will be higher. Based on this, the overall compression ratio of H.265 is 38,5% higher compared to its predecessor.

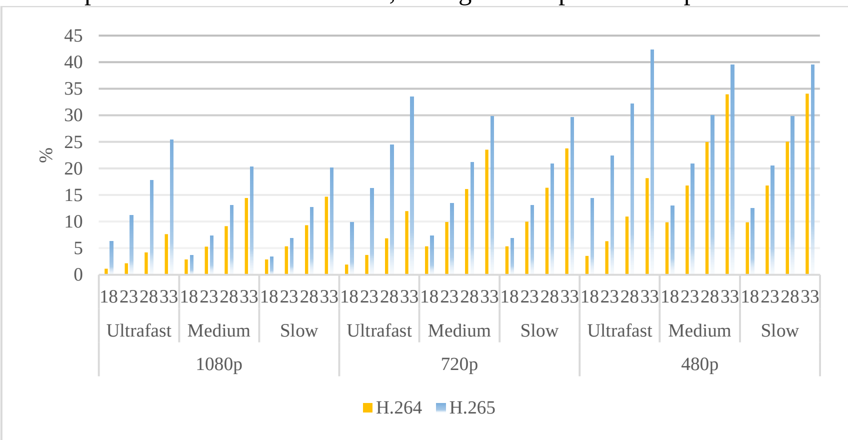


Fig. 2. Compression Ratio of H.264 and H.265

3.3 Bitrate

According to **Fig. 3,** it can be seen that the video output produced by H.264 has the highest bitrate (12,1 Mbps) with 1080p resolution, ultrafast preset, and CRF value 18. While the lowest bitrate is owned by the video output produced by H.265 (0,3 Mbps) with 480p resolution, ultrafast preset, and a CRF value of 33. Thus, the overall bitrate of the video output produced by the H.265 technique is 52,7% smaller than H.264. In addition, **Fig. 3** also shows that the lower the target video output resolution, but with the fastest presets and the highest CRF value, the resulting bitrate will be smaller.

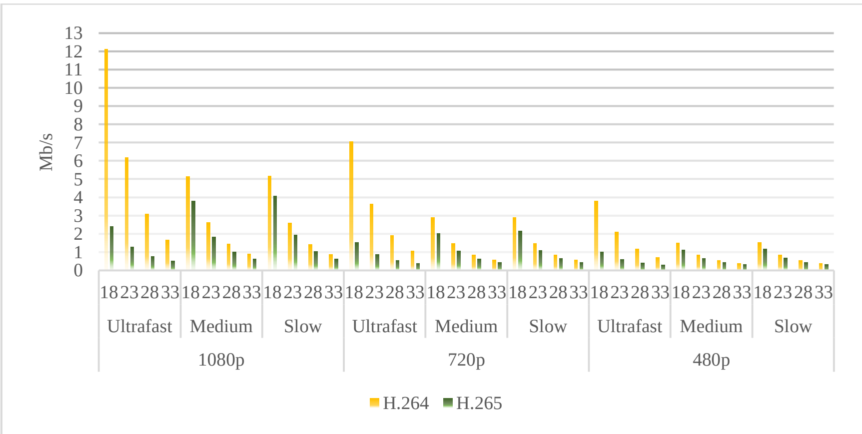


Fig. 3. Bitrate of H.264 and H.265

3.4 MSE and PSNR

According to Fig. **4** and **Fig. 5**, the video output produced by H.264 has the best quality (MSE = 1,52 and PSNR = 47,1) with 1080p resolution, slow preset, and CRF value of 18. While the video output produced by H.265 has the lowest quality (MSE = 4,5 and PSNR = 41,88), with a resolution of 480p, ultrafast preset, and a CRF value of 33. Thus the overall quality of the best video output is the result of H.264. Even so, the average quality of the output video produced by H.264 is only 0,5% greater than H.265, which means there is not too much difference between them.

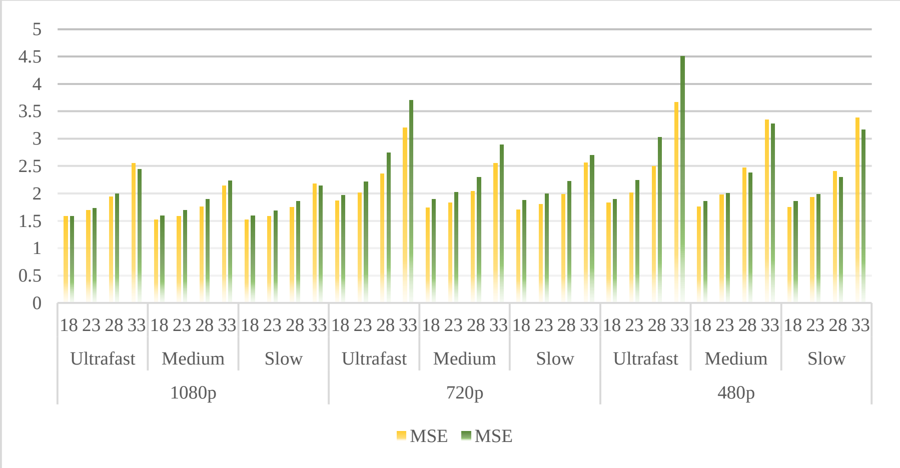


Fig. 4. MSE of H.264 and H.265

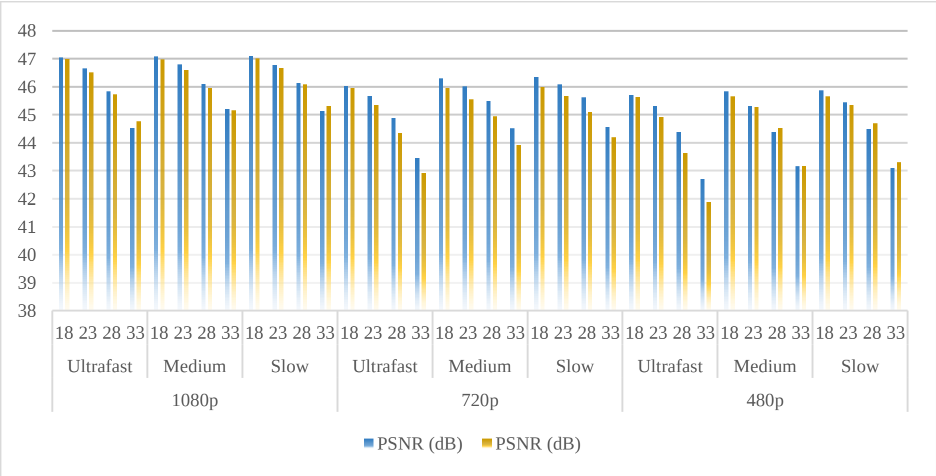


Fig. 5. PSNR of H.264 and H.265

3.5 Discussion

Overall performance of H.264 and H.265 to produced output video can be seen in **Table 1**. The average encoding duration of H.264 and H.265 are 708,8 s and 2358 s respectively. In other words, H.264 is almost 70% faster compared to its successor. In terms of bitrate, it turned out that the average H.264 bitrate is 2.3 Mbps, while the H.265 bitrate is 1,09 Mbps, which means the video output bitrate produced by the H.265 technique is nearly 53% smaller than that of H.264. Then in terms of compression ratio, the average difference between the size of the video source and the video output of H.264 and H.265 are 11,82% and 19,2%, respectively. Thus, the H.265 compression ratio outperformed H.264. Finally, the quality of video output produced from both techniques only has a slight difference, which is equal to 0,5%. This value showed that there is no significant difference in quality.

Table 1. Overall Performance of H.264 and H.265

Criteria	Encoding Duration (s)		Bitrate (Mb/s)		Compression Ratio (%)		MSE		PSNR (dB)	
	H.264	H.265	H.264	H.265	H.264	H.265	H.264	H.265	H.264	H.265
MAX	1739	8881,7	12,1	4,082	34,06	42,36	3,667	4,503	47,1	47
MIN	287,33	461,33	0,38	0,295	1,153	3,427	1,52	1,58	42,69	41,88
AVG	708,83	2357,6	2,3	1,086	11,82	19,2	2,124	2,261	45,41	45,2
Difference	69,9%		52,7%		38,5%		6,1%		0,5%	

Although developed by the same organization, in general H.265/HEVC is superior compared to its predecessor. This was consistent with [3] that stated H.265 has a bit-rate of nearly 50% lower compared to H.264 because of the adoption of several advanced encoding techniques. H.265/HEVC partitioned images into Coding Tree Blocks (CTBs). Similar to its predecessor, HEVC support quarter sample precision motion vectors and also supports various reference pictures, such as the concepts of I, P, and B frame slices which are basically inherited from H.264. Predictions using weight are also supported in a similar manner. The prediction is carried out by using the Advanced Motion Vector Prediction (AMVP) algorithm. All syntax data slice elements are entropy encoded with CABAC, which is similar to H.264/AVC. In addition to the deblocking filter, the HEVC design also includes a Sample-Adaptive Offset (SAO) operation inside the motion compensation loop.

Despite its advantages, it turns out that H.265/HEVC is an expensive concept to implement in commercial use, especially for video streaming companies due to royalty distribution policies [22] [23]. To overcome this, the Alliance for Open Media (AOMedia) was formed with the aim of developing a royalty-free video codec, which is the recently launched AOMedia Video 1 (AV1) [24]. As companies included in the AOMedia group sparked their adoption of the new video encoding format, industry and academic interest in AV1 has increased [22]. During the adoption of this latest technology, these companies must update their HEVC-encoded bitstreams into a new free-royalty format. In addition, users will also choose to re-encode their personal videos, which aims to reduce storage needs, especially for Ultra High Definition (UHD) videos. With the new technique and has its own characteristics, competition for encoding techniques will be tighter. In addition, various evaluations of both (free and non-free techniques) are also interesting research, especially with different configurations or implementation environments.

4 Conclusion

Based on the data obtained from the results of the study, several conclusions can be drawn. Each video encoding technique has advantages and disadvantages. From several testing parameters, the H.264 technique is superior in terms of encoding duration and the resulted video quality. Nevertheless, the difference in video quality was not so significant (similar) compared to H.265. In addition, if the user wants to prioritize good quality video output without having to sacrifice a lot of compression time and small file size, then our recommendation is to use H.265 encoding and by selecting an HD resolution configuration (720p) with medium presets and CRF 18 values.

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