Determining Bitrate Requirement for UHD Video Content Delivery

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***Abstract*-- In this paper, our objective is to identify the best possible bitrate for transmitting Ultra High Definition (UHD) content at different complexity levels and frame rates. We compressed several UHD videos at different bitrate levels and evaluated their quality through subjective tests. Results revealed that when the original videos are not available, naïve viewers cannot distinguish the difference in quality for bitrates above 5.6 megabits per second (Mbps).**

I. Introduction

The recent evolution of capturing technology, has led to higher quality content, with 4K resolution videos attracting the attention of professional content providers, camera and display manufacturers, broadcasters and consumers. With the availability of Ultra High Definition (UHD) Televisions in the consumer market, one of the main concerns of broadcasting and service providing companies is providing consumers with high quality UHD content at the lowest possible bitrate (recall that the resolution of 4K content is four times that of HD). In general, guaranteeing of delivering a specific level of visual quality (experience) is a challenge as it, leads to variable bit rates, which directly depend on the complexity of the video content [1]. Given that and the constraints added by the decoder buffer size and network bandwidth, UHD becomes a new challenge for service providers in their effort to deliver the best possible UHD quality to their customers while facing limited network bandwidth availability. Fortunately, thanks to the high compression efficiency of the recent video coding standard, H.265/MPEG-HEVC [2], UHD content delivery is becoming an easier task.

In this paper, our objective is to identify the appropriate bitrate for the transmission of UHD content. To this end, different UHD content with different complexity levels and frame rates is first coded at several fix bitrates and then the visual quality is tested subjectively. We allow encoder settings to be chosen according to the requirements of the service providers. We calculated the Mean Opinion Score (MOS) to determine the appropriate bitrates at different complexity levels or frame rates.

II. UHD Video Testset

In order to identify the appropriate bitrate for compressing UHD video sequences, we chose several representative UHD videos with various complexity levels from different databases. The specifications of the test videos are summarized in Table I. In order to study the effect of the frame rate and since the UHD display used in our study can support up to 60 frames per second (fps), the test videos with the frame rate of 120 were down-sampled to 60 fps by dropping every other frame. Similarly the sequences with 60 fps and 50 fps were down-sampled to 30 fps and 25 fps, respectively. For each test video the Spatial perceptual Information (SI) and Temporal perceptual Information (TI) were calculated according to the ITU-T recommendation P. 910 [5]. Table I includes the TI and SI information of the test sequences before down-sampling. Note that the down-sampled videos would have almost similar SI but different TI.

III. HEVC Encoder Settings

In this study, test videos are coded using the HEVC compression standard. We used the x265 encoder software, which is an open source implementation of the HEVC compression standard [6], for its improved features such as the adaptive-quantization-1 mode that gives better subjective quality and its significantly higher speed over HM HEVC [7]. To ensure our study complies with industry practices, the encoder settings are chosen to meet the requirements of service providers. The rate control mode is enabled and single pass coding is used. The following fix bitrates are chosen in our experiment: 1.5, 3.5, 5.6, 7, 10, and 15 megabits per second (Mbps). To improve rate control decisions, we applied a 4-second video buffer verifier (VBV) buffer depth, 4-second group of picture (GOP) length, and 4-second coded picture buffer (CPB) delay. We used the very-slow preset to trade

TABLE I
Specifications of The Test Sequences

Sequence	UHD_C	UHD_D	UHD_E	Beauty	ReadySetGo	Pedestrian
Resolution	3840x2160	3840x2160	3840x2160	3840x2160	3840x2160	3840x2160
Frame Rate	50	50	50	120	120	30
Number of Frames	500	500	500	600	600	300
Spatial Complexity (SI)	medium (80.5)	low(47.1)	low(36.1)	High(177.1)	High(177.3)	medium(110.4)
Temporal Complexity (TI)	low (19.53)	low(19.99)	low(17.70)	medium(69.40)	High(105.26)	low(12.77)
Bit Depth	8	8	8	10	10	8
Color Space	YUV 4:2:0	YUV 4:2:0	YUV 4:2:0	YUV 4:2:0	YUV 4:2:0	YUV 4:2:0
Source	BBC	BBC	BBC	TUT[3]	TUT[3]	DML-UHD [4]

encoding speed for compression efficiency and specify rate distortion and motion estimation parameters. We also enabled the psycho-visual options and aq settings, for maintaining the best perceptible video quality.

IV. Subjective Tests

We conducted our subjective tests using the single-stimulus adjective categorical judgment method according to ITU-R BT. 500-13 [8]. Eighteen subjects participated in our study. We conducted six test sessions with three subjects participating in each one. Observers were screened for color blindness and visual acuity. For viewing we used a 65-inch LCD 4K back projection display. The environment setting was according to [8]. In order to help subjects become familiar with the testing procedure, we had a training session using the "Pedestrian" sequence as the training source. During the test session, sequences of the same scene with different bitrates were presented randomly. For each scene, the 10-second long compressed test videos were followed by a 5-second long gray period to allow for voting. The 5-second long test sequences were played twice. For different test sessions the order of the scenes was randomized. For each test video, subjects had to vote for the quality of the content by assigning a mark between 1 to 5, where 1 stands for bad, 2 for poor, 3 for fair, 4 for good, and 5 for excellent. After the subjective experiment, the MOS was calculated and outlier detection was performed according to [8]. No outliers were detected.

V. Results and Discussion

The subjective test results with 95% confidence interval for sequences with low (25/30 fps) and high (50/60 fps) frame rates at different bitrates are illustrated in Fig. 1, and Fig. 2,

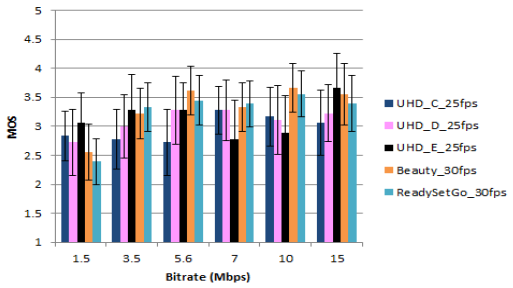

Fig. 1. MOS for 25 and 30 fps test sequences at different bitrates with 95% confidence interval

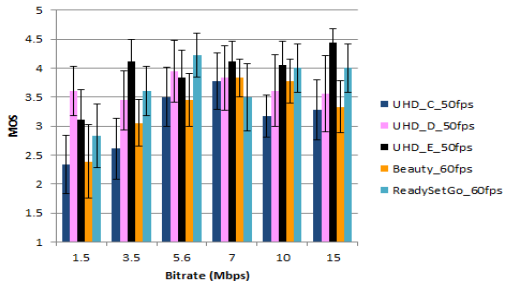

Fig. 2. MOS for 50 and 60 fps test sequences at different bitrates with 95% confidence interval

TABLE II
Statistical Differences Based on Student T-Tests: P-Values

Pairs	1.5Mbps vs 3.5Mbps	3.5Mbps vs 5.6Mbps	5.6Mbps vs 7Mbps	7Mbps vs 10Mbps	10Mbps vs 15Mbps
P-Value	0.02	0.14	0.92	0.95	0.78

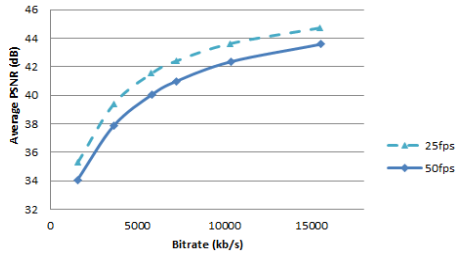

Fig. 3. Rate distortion curve for UHD-D 25 fps and 50 fps

respectively. As it is observed, the results are content dependent. Comparing Fig. 1 with Fig. 2, we observe that, for each sequence, high frame rates yield higher MOS. To investigate if there is a significant difference between the MOS at different bitrates, we performed the student t-test (see Table II), with null hypothesis being that MOS values for two compared bitrates are equal. We observe that, in general, for our test case of single-stimulus, where naïve viewers have no access to the original videos, the difference in quality for bitrates above 5.6 Mbps is not perceptible. However, if peak signal-to-noise ratio (PSNR) is used as a measure, then quality improves as the bitrate increases (see Fig. 3). This is a clear case where PSNR does not highly correlate with subjective quality evaluations. In order to obtain a better understanding of the bandwidth requirements for UHD content transmission, we are planning to perform double-stimulus impairment scale (DSIS) variant I subjective tests [8] in a "Side by Side" presentation over a much larger UHD video dataset.

VI. Conclusion

In this paper, our objective is to identify the appropriate bitrate for transmitting UHD content. We compressed different UHD contents at several bitrate levels. We performed single-stimulus subjective tests to collect observers' opinion on the quality of these videos. The results show when the original videos are not available, naïve viewers cannot distinguish the difference in quality for bitrates above 5.6 Mbps.

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