Analysis of two different HEVC encoding presets for resolutions up to UHD-1

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***Abstract*—Abstract**
***Index Terms*—4k, videoquality, VMAF, bitrate ladder**

I. Introduction

Broader access to online content[[cite something]] combined with and increased diversity of available content[[cite something]] has lead to a saturation of internet traffic. This issue has been mitigated through changes in how content is delivered, these changes include more intelligent delivery approaches such as using content delivery networks (CDN) [1] and Adaptive BitRate (ABR) streaming [2]. These improvements go hand in hand with a need for improvements in quality of experience prediction relative to encoding parameters.

This paper aims at finding correlation between predicted quality and user ratings based on three different encoding parameters:

- Resolution ranging from 540p to 4k
- Bitrate ranging from sheisstotal to tomuch
- 7he m4g1c p4r4m3t3r

Several data has been collected in addition to user ratings, these data include:

- Feedback questions
- Behavior during subjective tests
- other?

II. Test Preparation

We will introduce our source videos and the selection process in Section II-A, go over how we encoded them in Section II-B and explain the rating framework and test setup for the perceptual test in Section II-C.

A. Video Selection

The selection of suitable sequences for the test is based on technical considerations and content.

1) Preconsiderations: There exists only a few public UHD-1 and 4k video databases respectively. They differ in content (scenario, field size, camera movement, illumination condition) as well as in technical aspects (resolution, frame rate, bit rate and color bit depth). To obtain reference video files for the subjective test, parts of the UHD-1 content from the databases are used (also called source video files). For our test we want to have a large variety between the reference video files to evoke different encoding properties. All the reference videos should have a duration of 10 seconds with no cuts inside. To avoid the influence of judder, the smallest permitted frame rate of the source videos is 50 frames per second (fps). Furthermore the smallest resolution considered to be 3840x2160. Moreover the frame rate of the reference video files is being adapted to consistent 50 fps and the resolution to 3840x2160 pixels.

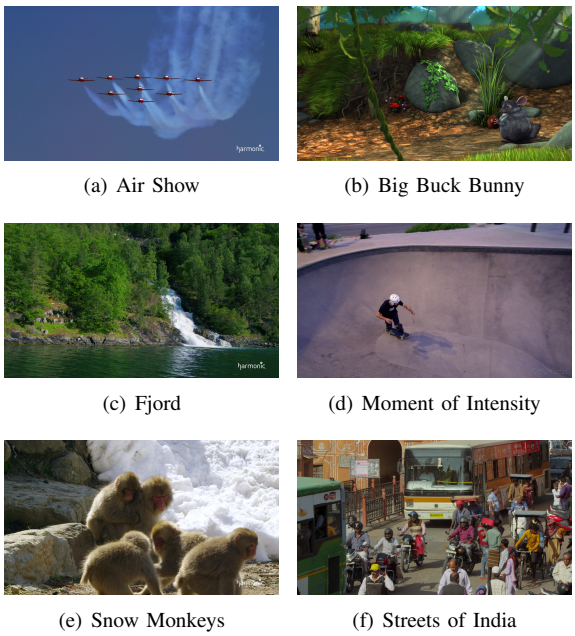
2) Dataset Preparation: For obtaining a good variety of video sequences three data bases are used: The Harmonic [3] which contains 18 different video files, Cable Labs [4] with 9 relevant UHD-1 contents and the Blender Foundation [5] for receiving the cartoon Big Buck Bunny. They are partial under the creative commence license and all of them are available in the ProRes format, except of Big Buck Bunny where the UHD-1 video content can be downloaded only as a compressed video file, however there also exist high quality PNGs for all the frames of the cartoon. In order to generate a high quality reference video with the frames of Big Buck Bunny, an automatisation script is used to find a sequence with a duration of 10 seconds, to download the respective images and to encode them as a video file. Generally, the challenge is to extract 10 seconds sequences from the original video files with no cut inside because there exists only a few.

One problem of the video sequences from the database is that even they have a high bit rate and are stored as ProRes, no conclusion referring to the contained visual quality can be done. If the videos were available in RAW, this would be preferred because RAW assures the least compression and no lost of information regarding the meta data. For this reason a preselection with a system, able to play 4k content in ProRes with high bit rates and connected to a 4k screen, was applied. The remaining reference videos are 6 source clips, each with a duration of 10 seconds. All the files have got a resolution of 3840x2160 pixels and are stored in ProRes. Because this format is a 10 bit codec only [6], the original color depth of each video file can not be determined. Further specific information about the reference videos are shown in Table I, e.g. Air Show, a video from the Harmonic Database, available with 59.94 fps and a bit rate of 1703 Mbit/s. For obtaining the reference video with a duration of 10 seconds the extraction starts at the 48.5 second of the source video file.

TABLE I
META DATA OF THE VIDEO FILES. THE TIMESTAMPS ARE THE START POSITIONS OF THE EXTRACTION OF 10 SECOND SEQUENCES FROM THE SOURCE FILES, WHERE MM STANDS FOR MINUTES, SS FOR SECONDS AND MS FOR MILLISECONDS RESPECTIVELY. FURTHER SHORTCUTS: H = HARMONIC, B = BLENDER FOUNDATION, C = CABLE LABS

Sequence Name	Frame Rate fps	Bit rate Mbits/s	Timestamps mm:ss.ms	Source
Air Show	59.94	1703	00:48.500	H
Big Buck Bunny	60	2304	05:47.000	B
Fjord	50	1469	00:21.000	H
Moment of Intensity	59.94	1822	02:16.000	C
Snow Monkeys	59.94	1750	00:17.000	H
Streets of India	50	2094	00:00.000	H

They contain a wide range of high-level features (animation, camera motion, people, water) and low-level characteristics (brightness, contrast, texture, motion, color variance, sharpness) as can be seen in Figure 1.



(a) Air Show (b) Big Buck Bunny

(c) Fjord (d) Moment of Intensity

(e) Snow Monkeys (f) Streets of India

Fig. 1. Selection of frames contained in the reference videos to show the variety of the content.

We further analyzed the information about the spatial and temporal changes between the frames of each reference video with SITI [7], a command-line-based tool that refers to ITU-T P.910, and diagrammed them in Figure 2. There the spatial information is computed by the maximum standard derivation of the results of a sobel filter applied on a frame. Furthermore the temporal information is the maximum standard derivation of the motion difference between two frames at the same location in space. As expected, Air Show includes the smallest spatial and temporal changes in comparison with the other reference videos due to the slightly changing and low complex scenario. Whereas the cartoon Big Buck Bunny shows a large range of temporal information by reason of camera movement and Snow Monkeys the highest spatial information according to fine structures and details. For generating the test data set the selected reference videos are encoded with different quality parameters.

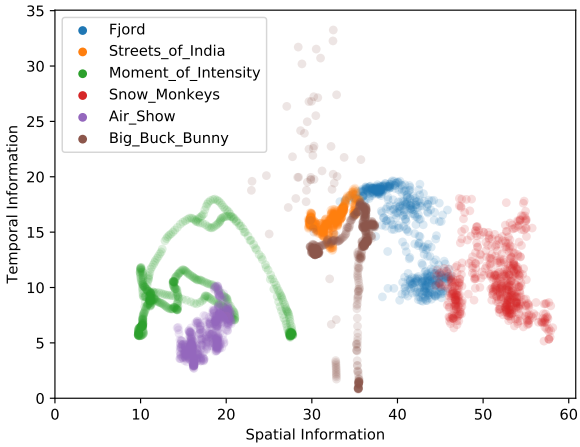


Fig. 2. Spatial and temporal information of the reference video files. Each dot represents one frame. In areas with high densities the color is stronger.

B. Encoding Parameters

The following section focuses on the encoding of sequences for the perceptual test and how we choose our selection of bitrate targets to limit the test duration.

1) Encoding Presets: We use the open x265 encoder for our experiment as it offers good performance and integration in the FFmpeg toolchain. Two different presets are used for the sequence encodings, a ”naïve” (P.1) and an ”expert” preset (P.2). The ”naïve” preset is a simple *CBR* (Constant Bitrate) encoding, whereas the ”expert” preset is a 2-pass encoding with a Quality-Control pass followed by a Bitrate-Control pass. Every sequence is encoded with both presets at 3 resolutions (540p, 1080p, 2160p) and 3 bitrates for each resolution. The following section goes into detail on how we select the bitrates.

2) Selection of Bitrates: Video Multi-Method Assessment Fusion (*VMAF*) is a full reference metric for estimating human perception of video quality [8]. We use *VMAF* because it provides a better estimate of subjective quality than single metrics like *SSIM* or *VIF*.

To estimate relevant *HEVC* encoding bitrates for our source content we sample the *VMAF* scores at 25 bitrates on a logarithmic scale for our 3 different resolutions (540p, 1080p, 2160p). The reference sequences are resampled to a fixed 50 frames per seconds to avoid frame rate differences, while the distorted sequences are downsampled, encoded with *CBR* rate control and upsampled to *UHD-1* again using lanczos resampling. Both presets use 4:2:0 chroma subsampling to be close to the typical use-case of webvideo. The sampling requires 222

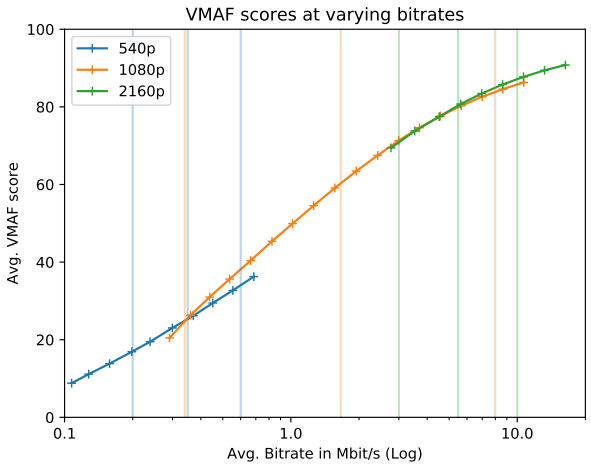


Fig. 3. Average *VMAF* scores for 25 different bitrates at 3 resolutions. The encoded bitrates and the *VMAF* scores are averaged between the 6 sequences and form the abscissa (Log) and ordinate respectively.

total sequences to be encoded with x265 and analyzed with the *VMAF Development Kit* (VDK). This process takes around 18 hours (excluding download and cutting of the source material) on a current 10-Core x64 CPU.

The resulting *VMAF* scores exhibit an overlap between different resolutions and the final encoding bitrates are chosen near those intersections. Figure 3 shows the sampled scores with the target rates in the background. We choose the target bitrates at least 2 bitrate-samples away from an intersection with the next quality, except for the lower 1080p-bound where it is not possible to lower the bitrate any further due to encoder restrictions. This should ensure a relevant sampling of the *MOS*-bitrate space for the subjective test.

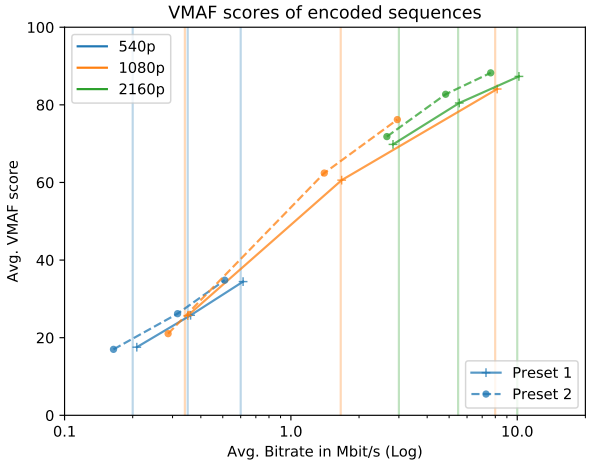


Fig. 4. Average *VMAF* scores of encoded videos for both presets. The encoded bitrates and the *VMAF* scores are averaged between the 6 sequences for each preset and form the abscissa (Log) and ordinate respectively.

The average *VMAF* scores of the two presets at the chosen bitrates can be seen in Figure 4. The target bitrates can again be seen in the background. The scores of the ”expert” preset are consistently higher than the ones for the ”naïve” preset at matching bitrates. Furthermore the ”expert” preset saves bitrate by resorting to an acceptable level of quality, while the ”naïve” presets bitrates are very close to the targets.

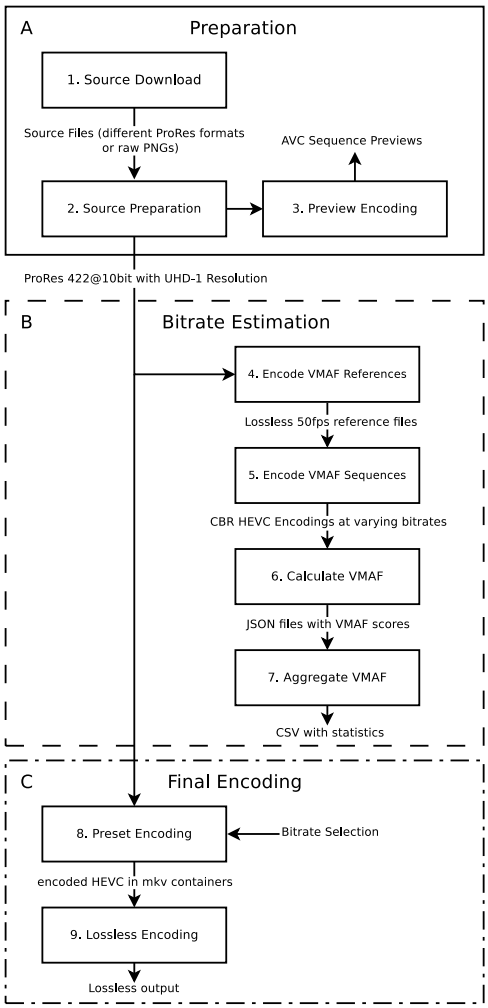


Fig. 5. Automated processing and encoding workflow.

3) Encoding Automation: We automate the whole process for downloading, preprocessing and encoding the source videos using pydoit [9]. This speeds up the turnaround time for changed parameters or sequences and also ensures that the encoded material can later be reproduced.

The whole process is illustrated in Figure 5 and starts with the source preparation (A). After download of the sequences (1) they are cut to 10 seconds length and saved as ProRes HQ with *UHD-1* resolution (2). Additionally, *MPEG4-AVC* previews are generated at a lower resolution of 1440p to allow review of the sequences on slower devices.

After the initial processing the bitrate estimation is performed (B) using the *VMAF* metric [8]. The videos are brought to the same frame rate of 50fps (4) and encoded with *CBR* at 25 different bitrates (5). The average *VMAF* score of each

video is analyzed with the *VMAF* Development Kit (VDK) [10] and saved as a json file (6). All of the scores are then aggregated into a single CSV for plotting and further analysis (7).

The last step is the main encoding (C). It can only start after the target bitrates have been selected manually. The sequences are encoded first with the two presets (8) and transcoded to a lossless format (ffvhuff) afterwards, to allow for fast and consistent playback as well as archiving of the video material.

C. Test Setup

Several steps have been followed in order to enable the acquisition of meaningful data during the subjective tests. Theses steps included defining the test environment, choosing a rating framework and creating additional question that may help inferring informations about the participants and their way of rating content.

1) Test Environment: In order to make the results of our research reproducible the ITU P.910 recommendation [11] have been followed. The parameters for the viewing conditions being:

a: Viewing distance
b: Peak luminance of the screen
c: Ratio of luminance of the screen, when displaying only black level in a completely dark room, to that corresponding to peak white
d: Ratio of luminance of background behind picture monitor to peak luminance of picture
e: Chromaticity of background
f: Background room illumination

As performing tests following these specifications is common at the Technical University of Ilmenau, a room meeting these requirements was available and therefore used. The specifications of the room was the following for each of the parameters:

a:
b:
c:
d:
e:
f:

2) Rating Framework: The testing procedure which seems more suited to the case was Absolute Category Rating (ACR) [11], where different versions of an original sequence are shown to a test participant.

For each sequence the participant issues categorical ratings from any of these 5 answers: {Excellent, Good, Fair, Poor, Bad}

The workflow of this rating framework is the following (see fig. 6):

1 Training phase: rating of reference videos
2 Registration phase: submission of personal informations
3 Rating phase: rating of 108 videos
4 End phase: feedback about the test

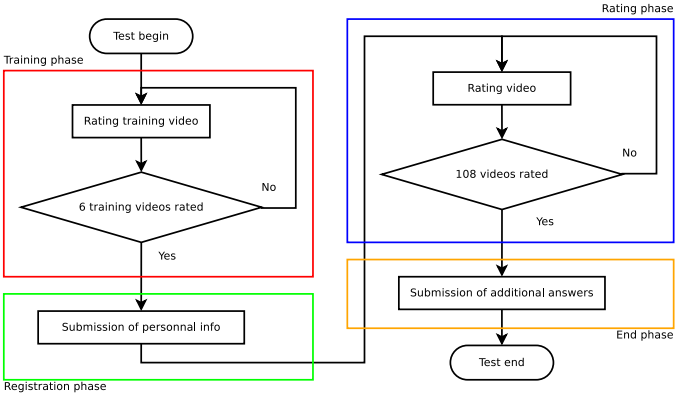


Fig. 6. Rating workflow

3) Additional collected data: In order to gain more knowledge about the users behaviour, additional data is collected from the participants.

One of the suggestions of the ITU recommendation paper being the usage of several test questions in addition to the ratings [11], the following questions have been asked at the end of each rating session:

- Presence of blocky artefacts
- Visible bands of colour
- Smoothness of the playback
- Have you seen 4K content before?
- Have you seen content on a 4k screen before?
- How sure were you about the rating that you provided?

These idea behind these question is dual as these questions may translate how users percieve/are sensitive to video features as well as how users may clearly express their perceptions. As it has already been noticed in previous experiments and in discussions with test participants: users may still rate using a different scales, thus spreading the final MOS or falsely being classified as outlier when their ratings may only represent a shift from the overall population.

Moreover, mouse interactions have been collected during the rating of each sequence. The intent behind this is that as the MOS scale doesn't allow detailed answers some participants may hesitate between two answers and change their answers or hover with their mouse around some answers. Also, answering speed, which could be an indicator of a participant skipping answers or to the contrary being strongly confident of his answers. We believe that several informations can be extracted from these kind of behaviours:

- Confidence in the participant sequence rating
- Confidence in the participant overall rating
- Intermediate scores (eg: 4.5)

III. Test Results and Analysis

TODO: Introduce Section

A. MOS Ratings

In this section we look at the results of the perceptual test and analyze them.

Compare preset *MOS*

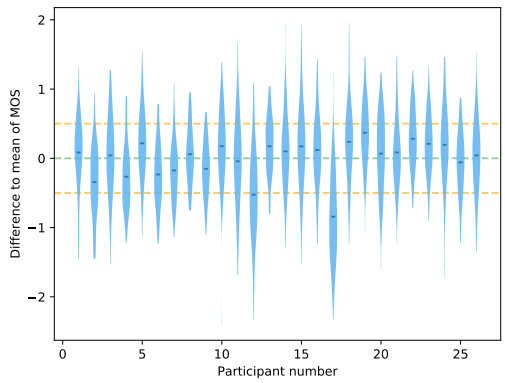


Fig. 7. Difference between average MOS and the invididual ratings for each participant

1) Outliers: We calculated the average of all *MOS* and compared the differences of each participants ratings to the average. This can be seen in 7. All participants apart from number 12 and 17 fall into a difference range of $[-0.5, 0.5]$ to the mean. For this reason we exclude the rating data of participants 12 and 17 from our further analysis.

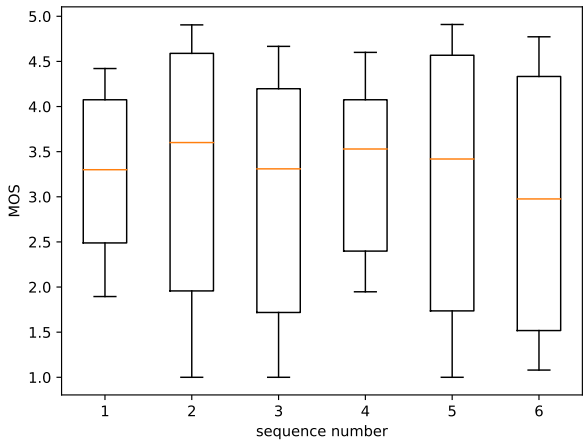


Fig. 8. *MOS* distribution per sequence over all versions of the sequence - 1: Air Show, 2: Big Buck Bunny, 3: Fjord, 4: Moment of Intensity, 5: Snow Monkeys, 6: Streets of India

2) MOS per Sequence: In Figure 8 we show the *MOS* for each sequence aggregated over all versions of this sequence. We see that the distributions are similar over all sequences and that every sequence has ratings on all steps of the *ACR* (Absolute Category Rating) scale. This suggests a broad range of qualities in the encoded video.

3) MOS per Sequence: The Distribution of *MOS* values for each preset at different resolutions is shown in Figure 9.

The "expert" preset is not using all available bitrate in critical low-bitrate situations. (Drop-Off for 1080p *MOS*), can already be predicted from VMAF plot.

Compare *MOS* with *VMAF* (correlation?)

The correlation between our determined *MOS* and the precomputed *VMAF* scores is very high at 93%. This can also be seen in Figure 12, where we illustrate the correlation for each preset per resolution.

B. Features

(Mouse tracking, Additional Questions)

IV. Conclusion

1) Conclude Stuff:

2) Future Work: Improvements of the automation framework: The source Preparation step could directly transcode the original material to a constant framerate and color-subsampling in a lossless format to avoid a further preprocessing step for the VMAF metrics.

A longer test or a sectioned test with more participants could provide a better sampling of the bitrate-MOS space and allow for more detailed analysis.

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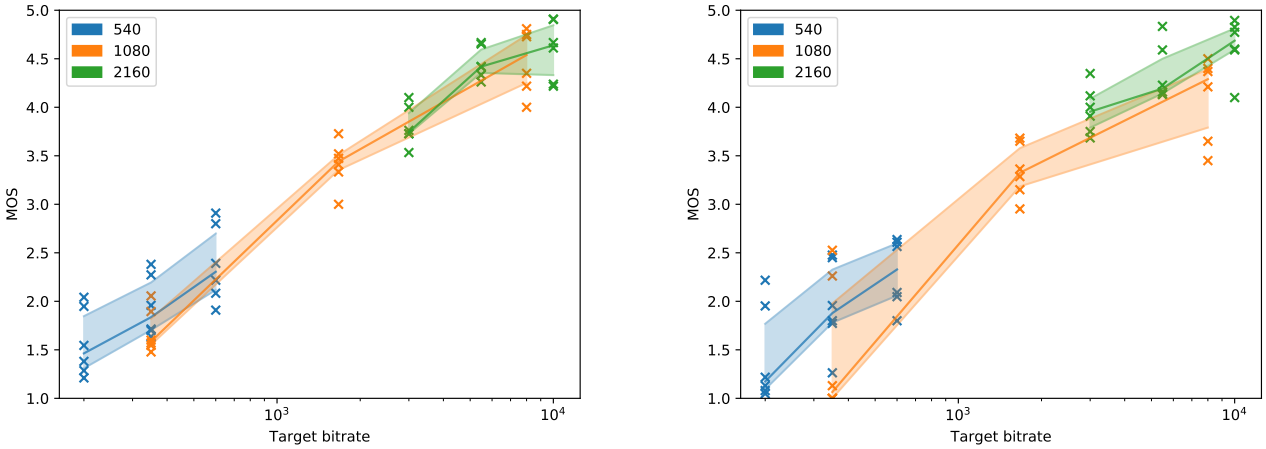

Fig. 9. Correlation between bitrate and *MOS* for both encoding presets. The center line represents a median and the outer line the 25th and 75th percentile of *MOS* for the 6 sequences.

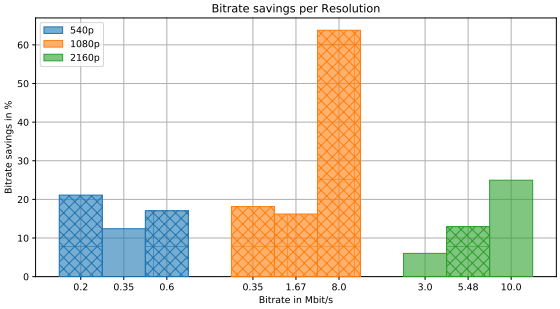

Fig. 10.

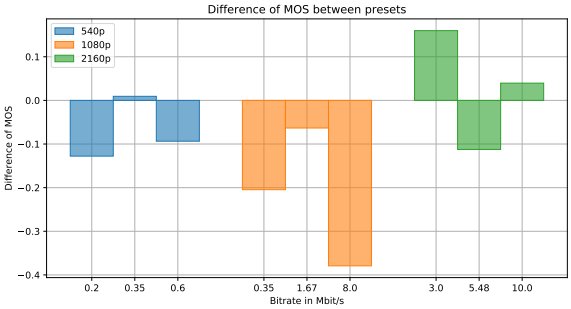

Fig. 11.

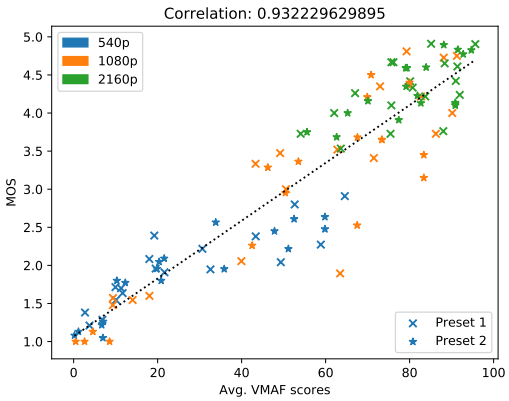

Fig. 12. Correlation between average *VMAF* scores and *MOS* for each preset and resolution

Fig. 13. Correlation between mouse related features and rating confidence

Fig. 14. Correlation between feedback related features and rating confidence

Fig. 15. Correlation between bitrate and MOS after correction based on mouse features

Fig. 16. Correlation between bitrate and MOS after correction based on feedback features

Fig. 17. Correlation between bitrate and MOS after correction based on mouse and feedback features