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UHD Quality Analyses at Various Viewing Conditions

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Abstract

As UHDTV programs are increasingly available, there are increasing needs for UHDTV signal measurement tools, which can estimate the perceptual quality of UHD signals compared to lower resolutions (e.g., 1080p). In this paper, the perceptual video quality of UHD signals is compared with other formats (1080p, 720p, 540p, 360p) when they are displayed on a UHD display. We performed a number of subjective tests using a UHDTV display at various viewing distance and the subjective scores of the various picture sizes are analyzed. Then, we propose some features that can be used to estimate the perceptual quality improvement of UHD signals compared to the lower resolutions.

Introduction

As UHDTV services are implemented as a next broadcasting and multimedia format, it will be desirable to develop measurement tools, which can be used to quantify the UHD signals. It has been reported that UHD signals may not always provide improved perceptual quality compared to the lower resolutions such full HD (FHD, 1920 x 1080). When compared to FHD, the perceptual quality improvement of UHD signals may not be significantly better as can be seen in Fig. 1. In this paper, we perform a number of subjective tests (UHD, 1080p, 720p, 540p, 360p; various viewing distances) and analyze the results. Then, we investigate which types of video/image may benefit from UHD resolutions.

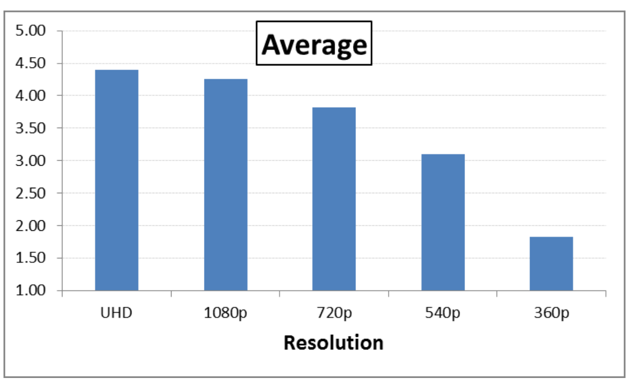

Figure 1. Perceptual quality comparison of various resolutions (averages of 40 SRCs, 3H).

Displays and Subjective Test

Displays

Three UHD displays were used in subjective tests, which include two TV monitors and a PC monitor. Table 1 shows the characteristics of the three displays used in the subjective tests. In some subjective tests, we used three viewing distances (1.5H, 2.3H, 3H).

Table 1. Subjective test conditions

Displays	75'' UHD, 65'' UHD, 32'' UHD
Signals	Video sequences, still images
Viewing distances	1.5H, 2.3H, 3H
Resolutions	UHD, 1080p, 720p, 540p, 360p

Subjective Tests

We selected high quality UHD resolution images and video sequences. In some subjective tests, we first reduced the images to 1080p, 720p, 540p and 360p. The reduced images were enlarged back to the original UHD resolution using an interpolation method. The original and enlarged lower resolution video/image signals were displayed on a UHDTV display. Perceptual picture quality scores were obtained through subjective tests.

The subjective tests were conducted in accordance with ITU-T Recommendation P.910 [1] and Recommendation ITU-R BT.500 [2]. As a subjective methodology, we used the absolute category rating (ACR) assessment method [1, 2]. Since it is a single stimulus method, a large number of test conditions can be included in a single session. In the ACR method, the viewer is shown a test sequence that is about 8~10 seconds and then is asked to score the video sequence. Table 2 shows the five grade scale of ACR along with description and Fig. 2 illustrates the ACR presentation. Normal vision screening was performed before the test and 24 viewers participated in each subjective test. When a viewer's subjective scores were substantially different from those of the others, such an unreliable viewer was replaced with a new viewer.

We performed three categories of subjective tests. In the first category, we performed several subjective tests to investigate the quality improvement of the UHD resolution compared to the lower resolutions (1080p, 720p, 540p, 360p). In this category, both image and video signals were used. In the second category, we investigated the effects of viewing distances on the perceptual quality of UHD signals. Finally, we performed a subjective test with two frame rates (30 fps and 60 fps) to understand the effects of frame rates on the perceptual quality of UHD signals.

Table 2. Five-grade scale of ACR.

Category	Score
Excellent	5
Good	4
Fair	3
Poor	2
Bad	1

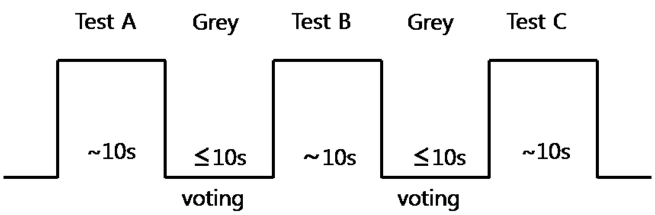

Figure 2. ACR presentation.

Experimental Results and Analyses

Quality improvement of UHD signals

In the first test, we selected high quality 40 UHD images and reduced the images to 1080p, 720p, 540p and 360p. The reduced images were enlarged back to the original UHD resolution using an interpolation method [3]. The UHD and enlarged lower resolution images were displayed on a UHDTV display. The viewing distance was 1.5H and the display monitor was 75 inches. Fig. 10 shows the perceptual quality comparison of the various resolutions. As can be seen, the difference between the UHD and FHD images are relatively small, though the UHD resolution produced better perceptual quality for some source sequences. Fig. 3 shows the average values of the 40 images and Fig. 4 shows the SI [1] and the noise information [4] of the images. We computed the noise information since FHD images look better than UHD images if the UHD images contains noises.

In the second test, we selected high quality 40 UHD video sequences and reduced them to the lower resolutions. The UHD and enlarged lower resolution video sequences were displayed on a UHDTV display. The viewing distance was 1.5H and the display monitor was 75 inches. Fig. 11 shows the perceptual quality comparison of the various resolutions and Fig. 5 shows the average values of the 40 video sequences. As can be seen, the video signals also show similar results. The differences between the UHD and FHD video sequences are minor, though the UHD resolution produced better perceptual quality for some source sequences as can be seen in Fig. 11. Fig. 6 shows the SI/TI information of the video sequences.

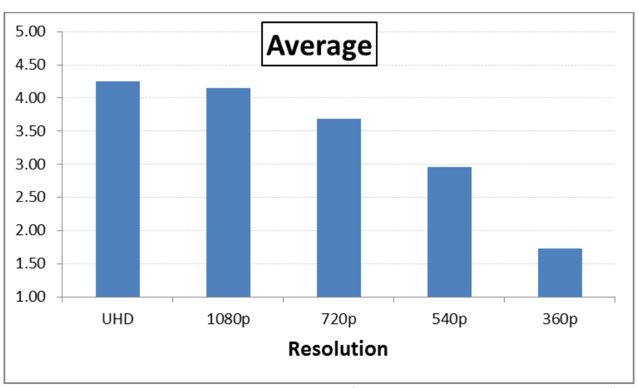

Figure 3. Perceptual quality comparison of various resolutions (average of the 40 images).

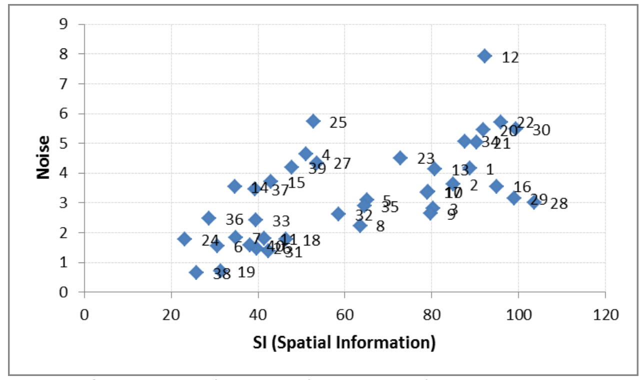

Figure 4. SI and noise information of the images of Figure 3.

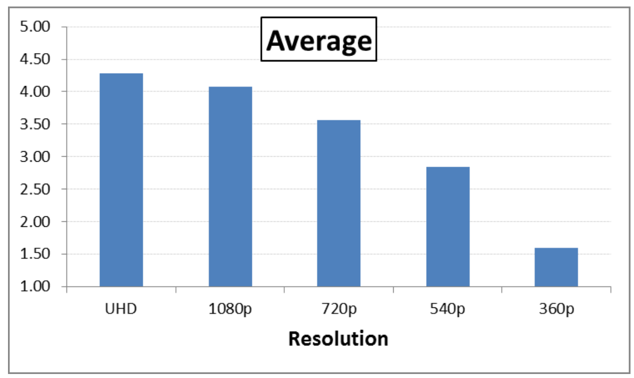

Figure 5. Perceptual quality comparison of various resolutions (average of the 40 video sequences).

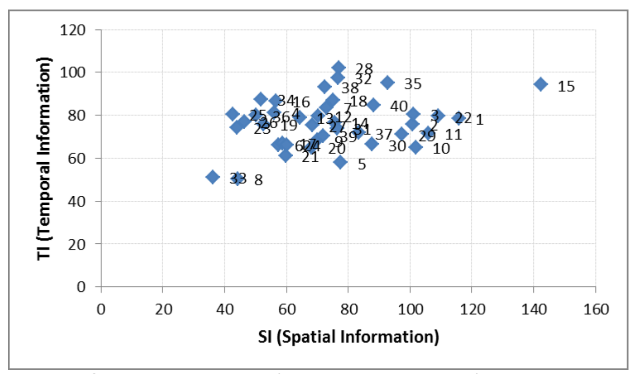

Figure 6. SI and TI distribution of the video sequences of Figure 5.

Viewing distances

In the next subjective test, 20 high quality UHD images were chosen. The UHD images were reduced to 1080p, 720p, 540p and 360p as previously. The original and enlarged lower resolution images were displayed on a UHDTV display at three viewing distances (1.6H, 2.3H, 3H where *H* represents the display height). The shortest distance (1.6H) is the viewing distance recommended by ITU-R Recommendations BT.2022 [5], which recommends the viewing distance so that the viewer can recognize each pixel. The viewing distance of 2.3H represents more realistic viewing distance in typical home environments. The longest distance (3H) would be a typical viewing distance for a large TV monitors (60 inches or higher). We used a 75 inches TV monitor. Perceptual picture quality scores were obtained through subjective tests. Fig. 7 shows quality comparison at the three viewing distances. As expected, as the viewing distance increases, the quality difference between the UHD and FHD images decreases. For the large TV monitor, the UHD signals are definitely better than 720p. Figs. 12-14 show quality comparison for each image at the three viewing distance and Fig. 15 shows the SI and noise values of the corresponding images.

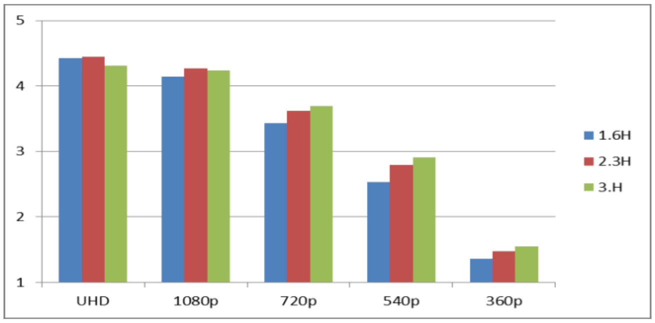

Figure 7. Quality comparison of the viewing distances (75" UHD display).

Frame Rates

Next, 20 high quality UHD video sequences (60 fps) were selected. The video sequences were reduced to 1080p and 540p. Then, the reduced video sequences were enlarged back to their original UHD sizes. The original and enlarged lower resolution video sequences were displayed on the PC monitor (32 inches) at two frame rates (30 fps and 60 fps). Fig. 8 shows quality comparison at the two frame rates. It appears that the quality differences between 60fps and 30 fps are relatively small. Fig. 16 shows the perceptual quality comparison for each video sequence. Fig. 9 shows the SI and TI values of the 20 video sequences.

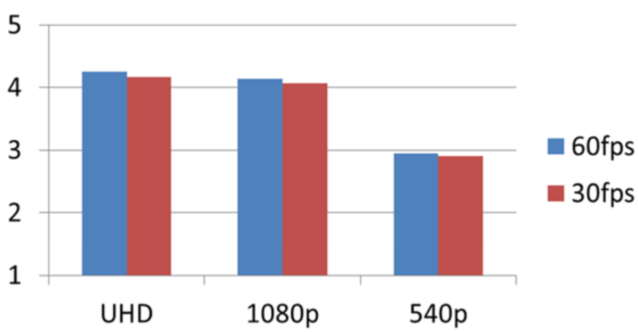

Figure 8. Perceptual quality comparison of two frame rates (average of the 20 video sequences).

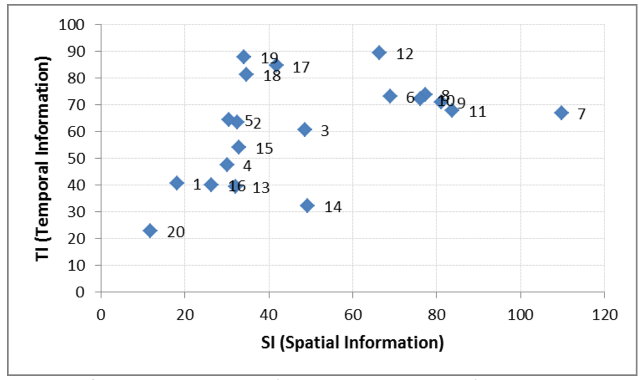

Figure 9. SI and TI distribution of the video sequences of Figure 8.

Predicting perceptual quality difference between UHD and FHD

We computed several features that can quantify the UHD signals, including spatial activity, high frequency levels, color information, etc. Fig. 17 shows the relationship between a feature and the difference between UHD and FHD subjective scores. The display was a 75 inches monitor and the viewing distance was 1.5H. The correlation coefficient is about 0.76, which is much higher than conventional SI or TI values.

Conclusions

In this paper, we analyzed the perceptual video quality of UHD signals in terms of resolutions, viewing distances and frame rates. We performed a number of subjective tests using a UHDTV display with various test conditions and analyzed the subjective scores. Based on the experimental results, some observations were made and a model was investigated to predict the quality improvement of UHD signals compared to FHD signals.

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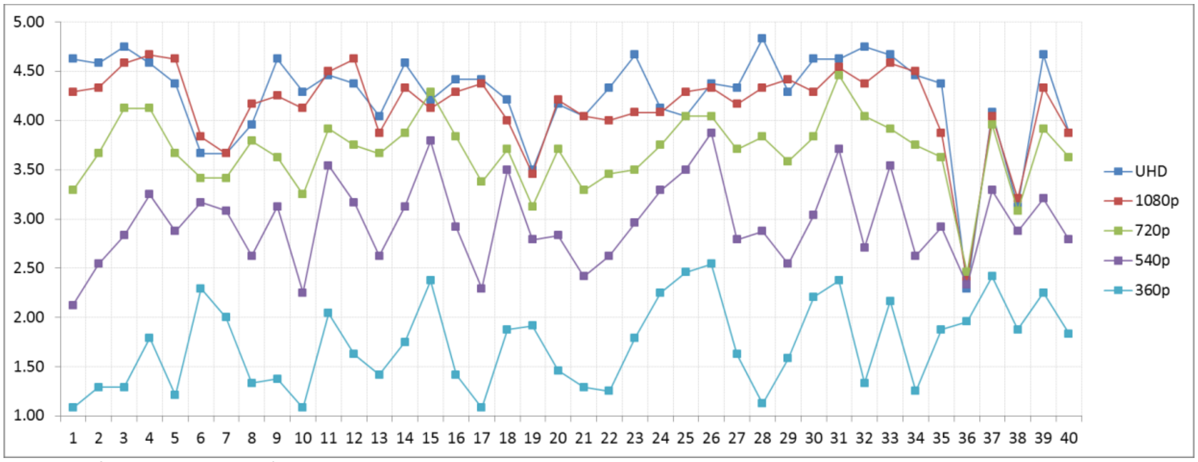

Figure 10. Quality comparison of the various resolutions (still images, 75'' UHD display, 1.5H).

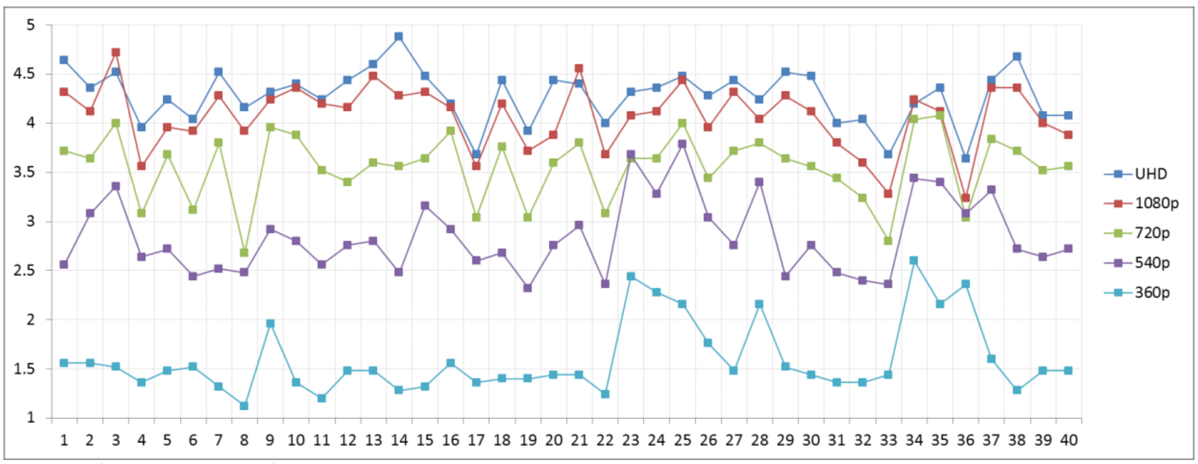

Figure 11. Quality comparison of the various resolutions (video sequences, 75'' UHD display, 1.5H).

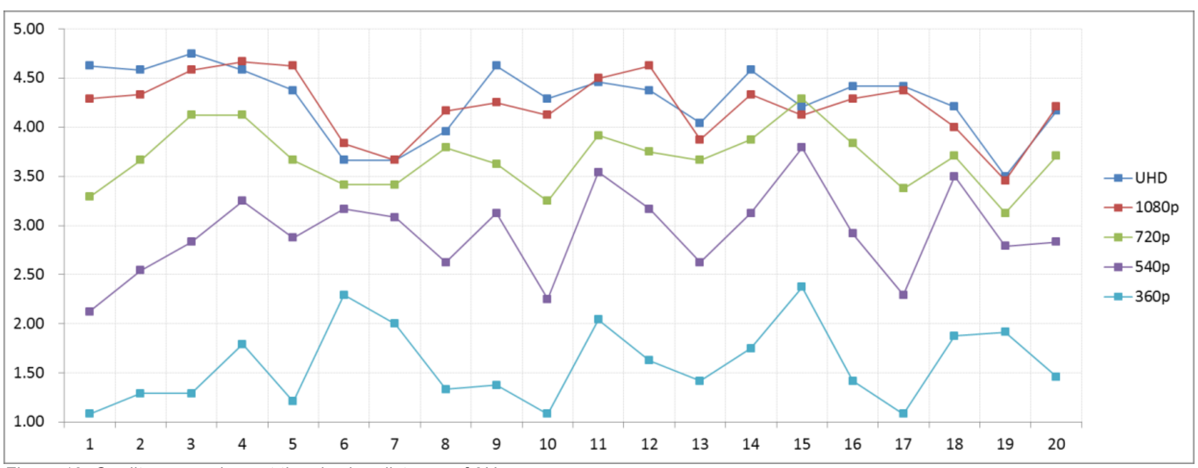

Figure 12. Quality comparison at the viewing distance of 3H.

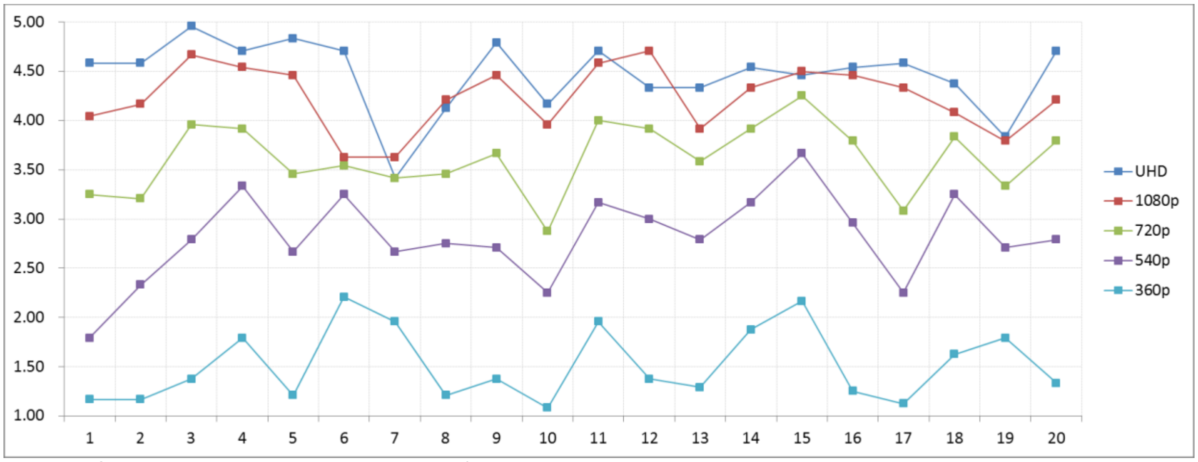

Figure 13. Quality comparison at the viewing distance of 2.3H.

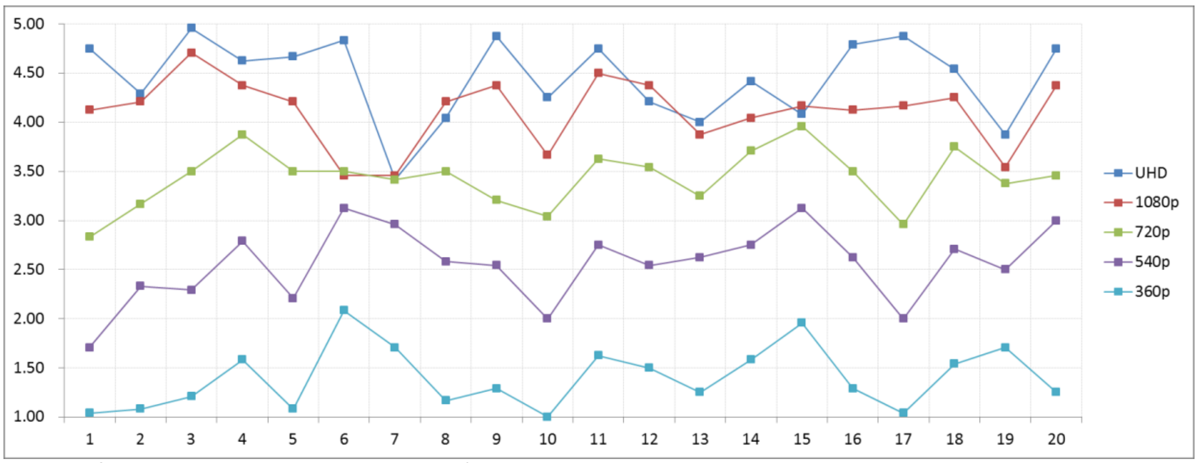

Figure 14. Quality comparison at the viewing distance of 1.6H.

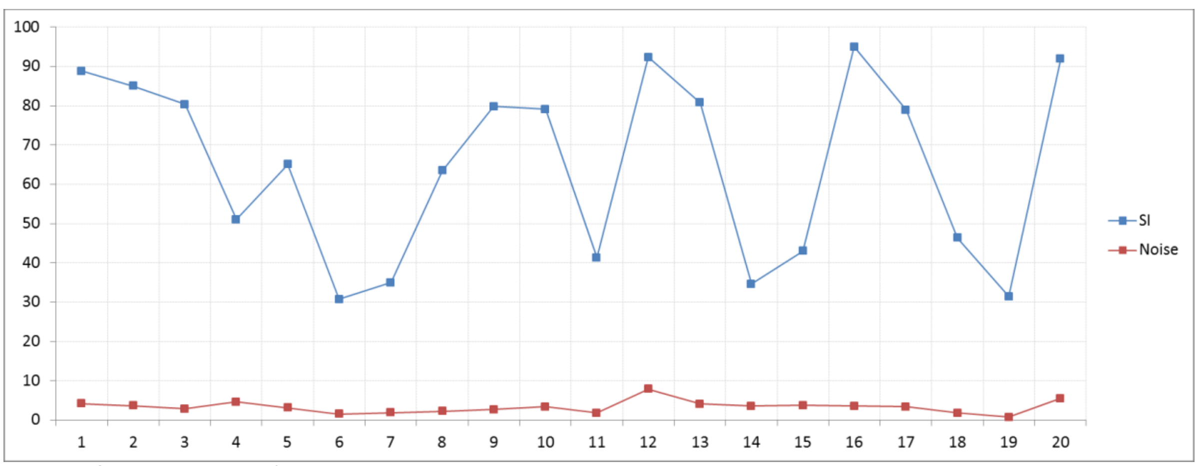

Figure 15. SI and noise values of Figures 12, 13 and 14.

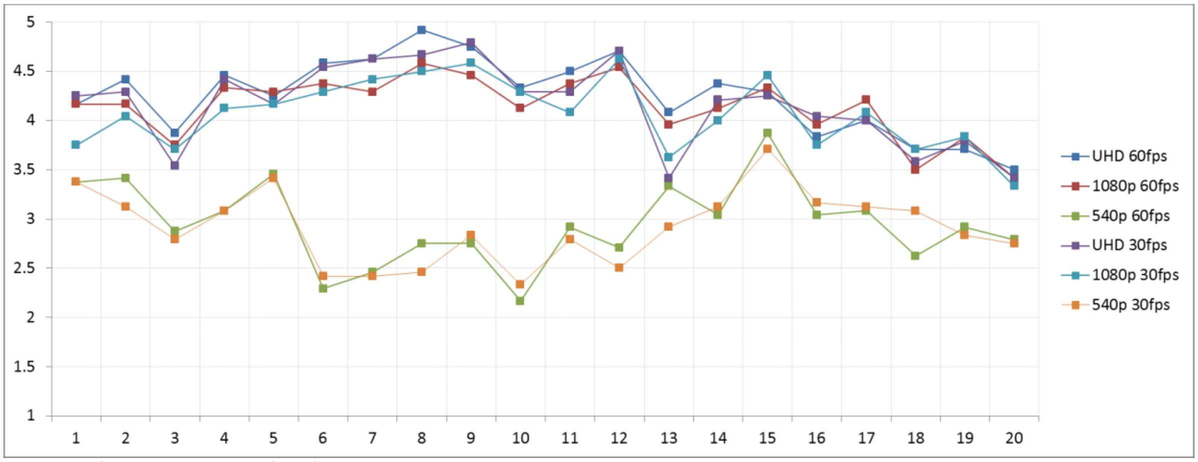

Figure 16. Quality comparison of the frame rates (75'' UHD display, 1.5H).

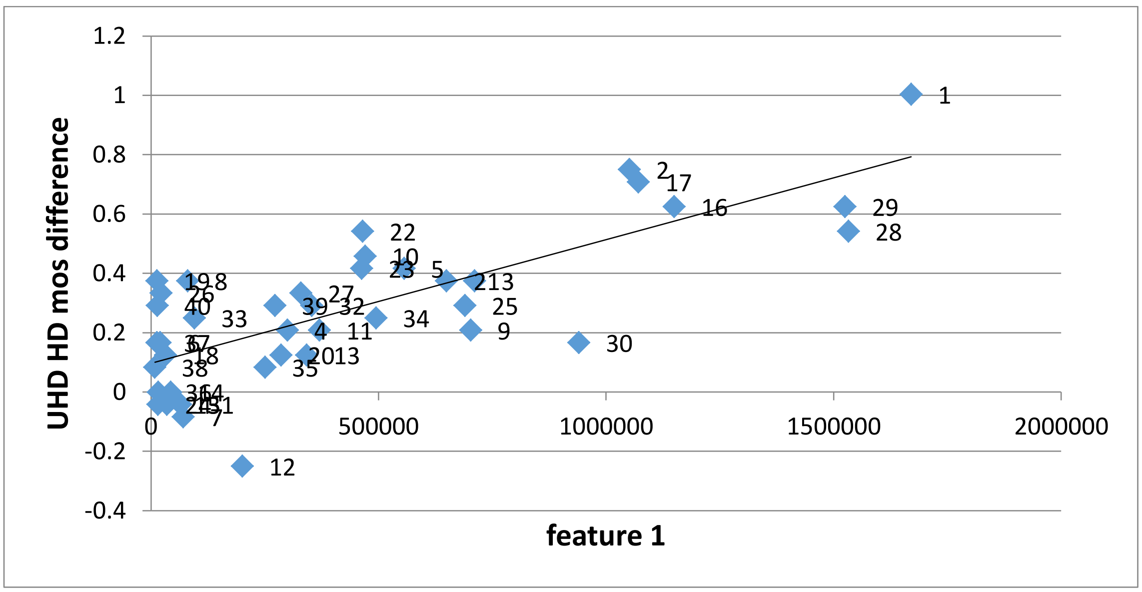

Figure 17. The scatter plot between the UHD-FHD MOS differences and the proposed feature.

Author Biography

Chulhee Lee received the B.S. and M.S degrees in electronics engineering from Seoul National University in 1984 and 1986, respectively, and the Ph.D. degree in electrical engineering from Purdue University, West Lafayette, Indiana, in 1992

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