On viewing distance and visual quality assessment in the age of Ultra High Definition TV

Patrick Le Callet, Marcus Barkowsky

Viewing distance and Quality assessment

The consumer video market is largely driven by the introduction of new formats (e.g., new pixel resolution). Each time, the story remains the same: what is the optimal viewing distance? Ultra High Definition TV is not an exception. This simple question is of crucial importance when it comes to the issue of quality and the added value of a new technology. In this letter, we revisit the topic, starting from best practices and then raising open questions.

Ultra High Definition (UHD) TV is following the tradition of enhancing Quality of Experience in consumer video. It notably offers the prospect of attaining a large field of view while fulfilling the limits of the Human Visual System (HVS) in terms of spatial and temporal contrast sensitivity. This should lead to a higher level of immersion which may reduce the influence of disturbing context influence factors by decoupling the observer from his environment. In order to ensure the adoption of the new technology by consumers, it is necessary to identify the conditions and limits under which the Quality of Experience is sufficiently increased. In this context, subjective experiments are useful to learn about the influence factors and provide meaningful guidelines. Visual distance, due to its close relationship with viewing field and immersion, is a key influence factor. In particular, as quality judgment might differ from one observer to another, well-defined experimental conditions are preferable, allowing for reproducibility from one individual to another or from one test environment or test lab to another. The viewing distance must be controlled and set under ad hoc rules.

Viewing distance and ITU recommendations: a (his)story of resolution

The ITU (International Telecommunication Union) has produced over the last decades numerous recommendations for the different parameters and conditions needed to conduct subjective quality assessment experiments. Usual controlled factors are the viewing distance, general ambiance (lighting, color of the walls...) and the display screen. Traditionally, the room setup and the display are chosen such that the detection of artifacts is as easy as possible for the observer.

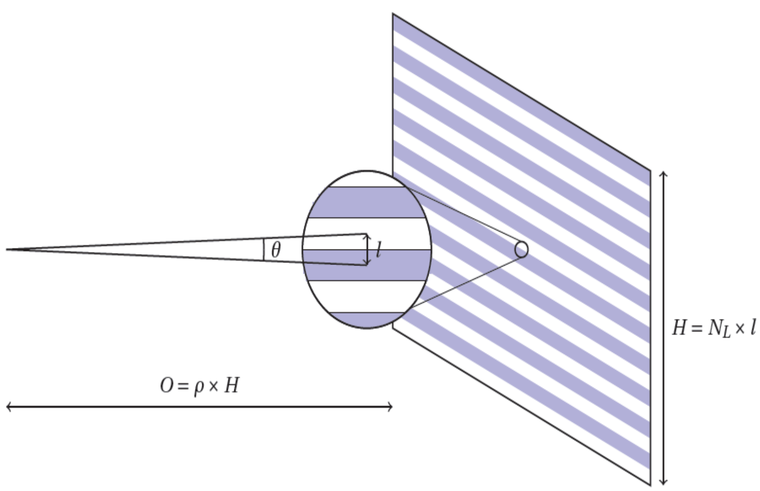

Figure 1. Viewing distance O and its related physical parameters

Historically, the ad hoc viewing distance depends on the number of lines of the image. To take maximum advantage of the resolution, the optimal position for an observer should correspond to the limit of visual discrimination between two lines. Discrimination power of a regular (normal vision) observer is on average one minute of arc, which corresponds to a critical pattern frequency of 30 cycles per degree (cpd). The angle between two lines as represented in Figure 1, can be computed using the equation:

$$\theta = 2.\arctan\left(\frac{1}{2.\rho.N_L}\right) \tag{1}$$

with N_L being the number of lines and ρ the ratio between the viewing distance and the physical height of the active screen area. Consequently, in the case of Standard Definition TV with 576 lines, one should be at a distance corresponding to:[2]

$$\rho = \frac{1}{2x576x\tan\left(\frac{1'}{2}\right)} = 5.98 \qquad (2)$$

which is around 6 times the image height. For 1080 line HDTV, this value is reduced to around three times the image height. This distance has a direct impact on the extent of the visual field that is covered by the image as reported in Table 1. The horizontal viewing angle α can be obtained as:

$$\alpha = 2.\arctan\left(\frac{Np}{N_L}\frac{1}{2.\rho}\right) \qquad (3)$$

with N_P the number of pixels on a line.

Table 1. Relative viewing distance and corresponding horizontal viewing field for different resolutions.

Resolution	Relative viewing distance (to the image height)	Horizontal Viewing Field (in degree)
SDTV (576 lines) [3]	5.98	11,93
HDTV (1080p) [4]	3.18	31.27
UHDTV (2160 lines) [5]	1.59	52.87

The critical frequency of 30 cpd can be considered as a lower bound for a usual observer. This value tends to increase depending on the contrast of the pattern, its speed, and the surrounding conditions (60 cpd can be considered as a higher bound).

[2] In (2) the unit of the input of the tan function is in minutes of arc.
[3] Aspect ratio (number of pixels per line/number of lines) is 1.25:1.
[4] Aspect ratio is 1.78:1.
[5] Aspect ratio is 1.78:1.

Figure 2 shows the relationship between the diagonal of the display, measured in inches, and the viewing distance in

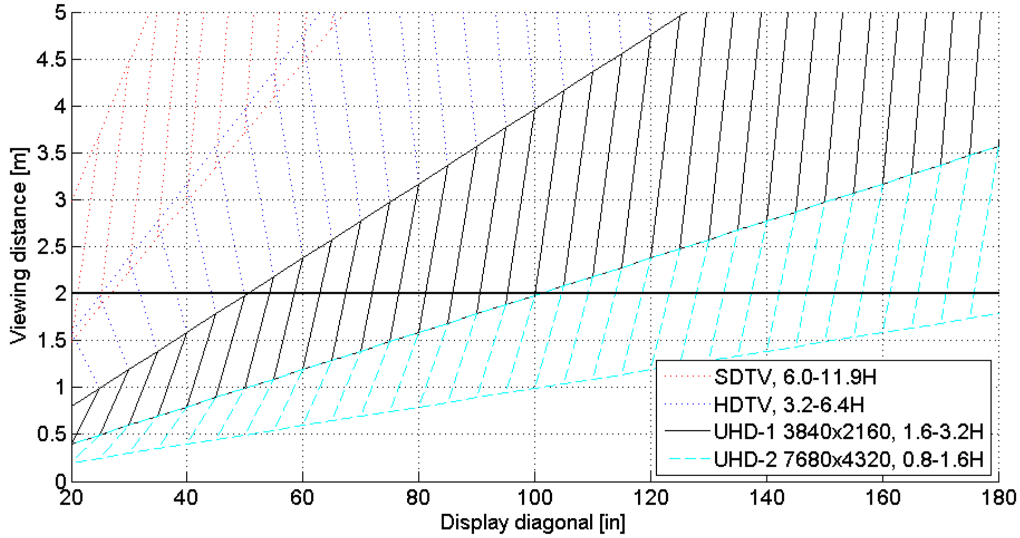

Figure 1. The relationship between absolute viewing distance in meters and the display diagonal in inch for the three resolutions HDTV, UHD1, and UHD2 when considering a range of resolution of the human eye of 30cpd to 60cpd. In home viewing, a typical absolute viewing distance may be considered as 2m. In case of line interleaved 3D displaying, the vertical resolution is halved, thus the next lower resolution applies.

meters for the four resolutions SDTV, HDTV, UHD1, and UHD2. The upper limit of the area provides the highest spatial contrast sensitivity that the HVS may support (60 cpd), notably when objects with a high-contrast texture at the critical frequency are moving at an average speed of about 0.15 degrees per second.[6] The lower bound of the area is calculated for 30 cpd, a retinal frequency that still avoids seeing the pixel grid in most cases. It has been previously used, for example in the case of HDTV[7] [3]. The diagram shows that for a typical viewing distance of 2 m in a living room, the size of the display needs to be significantly enlarged, i.e. up to 100 in (2.54 m) for UHD-1.

[6] Daly, S. Engineering Observations from Spatiovelocity and Spatiotemporal Visual Models. In IS&T/SPIE Conference on Human Vision and Electronic Imaging III., SPIE Vol. 3299, pp. 180-191, January 1998.
[7] Cermak, G., Thorpe, L., & Pinson, M. (2009). Test Plan for Evaluation of Video Quality Modelsfor Use with High Definition TV Content. Video Quality Experts Group (VQEG)

Viewing distance and UHD TV: revisiting the history?

When targeting higher resolution and consequently lower viewing distance and larger excited visual field, factors other than discrimination between lines might come into play and affect the comfort of the observer, especially when the perceived quality of the media is not sufficient. It has been observed[8] when comparing standard definition and high definition conditions that larger viewing field has a positive effect at high quality while it exhibits clearly negative effects at mid quality levels (standard definition is then preferred compared to high definition). More generally, the focus may shift from pure video quality evaluation to Quality of Experience (QoE),[9] which can lead to the concept of preferred viewing distance.

Higher resolution offers a reduction in viewing distance and an increase in viewing angle, implying better immersion and better Quality of Experience. To what extent is the last part of this statement valid?

For instance, it should be noted that for smaller display sizes, observers prefer larger viewing distances. This is partly due to the accommodation effort that is required when the viewing distance is inferior to 1 m, a distance that may even imply focusing difficulties for senior viewers. It has also been shown recently[10] that illumination conditions may influence the

[8] S. Péchard, M. Carnec, D. Barba, et others, « From SD to HD television: effects of H. 264 distortions versus display size on quality of experience IEEE International Conference on Image Processing, ICIP, 2006, p. 409–412.

[9] a term which aims at evaluating the overall satisfaction of the user. It has been recently defined as "…the degree of delight or annoyance of the user of an application or service. It results from the fulfillment of his or her expectations with respect to the utility and / or enjoyment of the application or service in the light of the user's personality and current state". Patrick Le Callet, Sebastian Möller and Andrew Perkis, eds , "Qualinet White Paper on Definitions of Quality of Experience (2012). European Network on Quality of Experience in Multimedia Systems and Services (COST Action IC 1003),., Lausanne, Switzerland, Version 1.2, March 2013

[10] Lee, D. - S., & Shen, I. - H. (2012). Effects of illumination conditions on preferred viewing distance of portable liquid-crystal television. Journal of the Society for Information Display, 20(7), 360–366.

Patrick Le Callet is full professor at Ecole polytechnique de l'Université de Nantes. Since 2006, he is the head of the Image and Video Communication lab at CNRS IRCCyN, a group of more than 35 researchers. He is mostly engaged in research dealing with the application of human vision modeling in image and video processing. He is currently co-chairs the "3DTV" activities and the "Joint-Effort Group", driving mostly High Dynamic Range topic in this latest. He is currently serving as associate editor for IEEE transactions on Circuit System and Video Technology, SPRINGER EURASIP Journal on Image and Video Processing, and SPIE Electronic Imaging.

Marcus Barkowsky received the Dr.-Ing. degree from the University of Erlangen-Nuremberg in 2009. He joined the Image and Video Communications Group at IRCCyN at the University of Nantes in 2008, and was promoted to associate professor in 2010. His activities range from modeling effects of the human visual system, in particular the influence of coding, transmission, and display artifacts in 2D and 3D to measuring and quantifying visual discomfort and visual fatigue on 3D displays using psychometric and medical measurements. He currently co-chairs the VQEG "3DTV" and "Joint Effort Group Hybrid" activities

preferred viewing distance as well, which may be explained by the fact that the contrast sensitivity increases with higher illumination.

Moreover, while a higher level of immersion or presence is usually perceived as advantageous, it may also introduce discomfort issues. Because of the larger field of view, simulator sickness may occur due to the decoupling of the visual stimulus with the sense of balance. This is particularly true for fast camera movements.

As UHD content is currently not very widespread, and the habits of consumers nowadays include watching online available content that is often only available at lower resolutions and reduced quality, the optimal viewing distance may vary with the usage condition in the home environment, i.e., smaller viewing distance when watching high quality UHD content and larger viewing distance when watching low quality web content. In some conditions, it may also prove advantageous to reduce the active screen size in order to avoid visual discomfort issues such as simulator sickness. While one could stick to the original ITU methods, optimal guidelines on viewing distance might need to be developed both for lab experiments as well as for the home environment, in particular for large UHD displays.