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SERIES P: TERMINALS AND SUBJECTIVE AND OBJECTIVE ASSESSMENT METHODS

Audiovisual quality in multimedia services

Display requirements for 3D video quality assessment

Recommendation ITU-T P.914

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Recommendation ITU-T P.914

Display requirements for 3D video quality assessment

Summary

Recommendation ITU-T P.914 specifies the requirements for the selection of three dimensional (3D) displays when conducting subjective quality assessment experiments.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T P.914	2016-03-15	9	11.1002/1000/12776

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Introduction

Compared to two dimensional (2D) video, several new issues have arisen in three dimensional (3D) video applications and 3D display technologies still face some challenges. It is therefore important to take into account the potential suboptimal rendering of the 3D display when assessing the 3D viewing experience. It is also important to characterize and report properly the 3D display characteristics in the context of subjective testing as this information helps in correctly interpreting subjective results. In particular, three dimensional televisions (3DTVs) exhibit crosstalk to various degrees and can negatively impact the viewing experience. Crosstalk is a major factor in video quality, visual discomfort and visual fatigue problems.

Recommendation ITU-T P.914

Display requirements for 3D video quality assessment

1 Scope

This Recommendation provides guidelines for the selection of 3D displays for consistent and repeatable subjective video quality assessment in the context of entertainment content and consumer quality. This Recommendation also provides guidelines for appropriate room environmental constraints that ensure visibility of the stereoscopic effect.

1.1 Applications

The applications for the 3D display requirements described in this Recommendation include, but are not limited to:

- Minimum requirements for 3D display in the context of subjective quality assessment of 3D video;
- Consistent and repeatable quality assessment of 3D video sequences.

The applicable services for this Recommendation include:

- Cable TV;
- Streaming video;
- Internet protocol television (IPTV);
- Mobile video applications;
- Interactive video applications.

This Recommendation is intended for use with stereoscopic 3D displays, such as:

- Linearly and circularly polarized glasses for view separation;
- Active shutter glasses;
- Stereoscopic and multiview lenticular array autostereoscopic displays;
- Stereoscopic and multiview parallax barrier displays;
- Multiple spectral bandpass filters, a type of enhanced colour separation filters.

1.2 Limitations

This Recommendation only applies to video quality assessment of coding and transmission error scenarios where the 3D video sequences are moderately to strongly degraded. More stringent display requirements may be needed to accurately assess quality in the presence of nearly lossless quality impairments (e.g., where the quality is nearly the same as the original 3D video).

This Recommendation contains insufficient information for the following applications:

- While most of the information provided herein applies, additional constraints are required for medical applications;
- Immersive, virtual reality environments (e.g., gaming, caves, head-mounted displays);
- Augmented reality.

This Recommendation contains insufficient information on overall illumination and display brightness levels for:

- Mobile devices (e.g., laptops, tablets, phones).

The following display technologies are inappropriate for subjective testing, and as such fall outside the scope of this Recommendation:

- Anaglyphic colour separation filters.

This Recommendation is not intended for use with holographic displays, light field displays, volumetric displays and stereoscopes (e.g., mobile smartphone 3D). The usage of touchscreens in conjunction with 3D displays is outside of the scope of this Recommendation, in particular depth conflicts arise between the depth planes used for displaying contents and the real-world user interaction. User interactions with a 3D touchscreen are outside the scope of this Recommendation (e.g., because a user' fingers enter into the virtual space and they obstruct the eye contact with the stereoscopic reproduction).

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T P.916] Recommendation ITU-T P.916 (2016), *Information and guidelines for assessing and minimizing visual discomfort and visual fatigue from 3D video*.

3 Definitions

This Recommendation uses the following term defined elsewhere.

3.1 Terms defined elsewhere

3.1.1 visual comfort zone [ITU-T P.916]: Visual comfort zone is defined as the depth interval which allows for 3D viewing without the introduction of visual discomfort.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 crosstalk: The amount of light perceived by the non-intended eye due to incomplete inter-view isolation.

3.2.2 overall illumination: The light coming from all light sources in the room, notably including both the light coming from the display and from the ambient room illumination. This is measured in lux.

3.2.3 view: The video produced by a single camera sensor (i.e., 2D video).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

2D Two Dimensional

3D Three Dimensional

3DTV Three Dimensional Television

AVC Advanced Video Coding

FPR Film-type Patterned Retarder

HRC Hypothetical Reference Conditions

IPTV Internet Protocol Television

MOS Mean Opinion Score

QP Quantization Parameter

SBS Side-By-Side

SG Shutter Glasses

SRC Source Reference Circuit

TB Top-Bottom

5 Conventions

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement need not be present to claim conformance.

The keywords "is prohibited from" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 3D display requirements

6.1 Display brightness and overall illumination

Display brightness (luminance) is measured as seen through the appropriate 3D glasses (if any). When the measurements are made, the system shall be used in three dimensional television (3DTV) mode. This means, for example in the case of an active shutter glasses (SG) TV, the glasses must be turned on and the measurement system must be synchronized with the shutter cycle. Refer to [b-IDMS1] for details on how to measure brightness for various types of displays.

6.2 Introduction to crosstalk

Crosstalk is the amount of light perceived by the non-intended eye due to incomplete inter-view isolation.

In the context of subjective quality assessment of 3D video, a suitable 3D display must be selected such that the display does not affect the reliability and reproducibility of subjective results. However, crosstalk is a major contributor to quality loss and visual discomfort on stereoscopic displays. It can therefore greatly impact the quality of experience in the viewing of stereoscopic 3D content and the results of subjective quality assessment.

To achieve consistent results in 3D video quality assessment, it is important to understand the maximum amount of allowable display crosstalk. Subjective testing requires measurement or characterization means to adequately select display equipment to conduct such subjective testing in a reliable and repeatable manner.

Several works in the literature and works presented to the Video Quality Experts Group have shown that obtaining objective physical measurements of 3D displays to characterize their crosstalk is not straightforward and repeatability of results is still an issue to be solved. There are many parameters (e.g., distance, angle, characteristics of the measurement instruments) that make physical measurements difficult and many aspects (e.g., non-uniformity, spatial/temporal variation, anti-crosstalk mechanisms) that make crosstalk difficult to represent as a single value.

6.3 Crosstalk measurements

[b-IDMS1] provides means of measuring crosstalk with respect to different display technologies.

6.3.1 Grey-to-grey crosstalk

Crosstalk is not necessarily only due to leakage of unintended white image/level onto intended black image/level, but may also be due to other grey-to-grey configurations (other grey-to-grey configurations may produce perceivable/visible crosstalk).

The selection of a 3D display for the subjective quality assessment of 3D content should not be based only on the measure of crosstalk using the leakage of light signals from the open to the blocked channel using a white image as the open channel signal and a black image as blocked channel signal, but should also consider the following aspects:

- The spatial variation of the crosstalk;
- The angular variation of the crosstalk (crosstalk off the center axis);
- Chromatic aspects.

6.3.2 Angular influence

Two angular influences must be taken into account:

1) A spatial measurement can record crosstalk variation depending on the eye gaze direction (e.g., position in the image). This already gives an angular indication of how the angular dependence of the liquid crystal shutter and the display angular emission are combined. In the case of LCD displays, light polarization and its interaction with the glasses polarization analyzers create specific effects altering image and crosstalk homogeneity.
2) Another angular variation depends on the observer's position in front of the screen. The same effects of direction-dependent light emission and of interaction between screen emission and glasses analysis will happen.

Because of the two points mentioned above, crosstalk measured at a specific angle can be dramatically more significant than a basic central measure on the screen normal axis. A single measurement at the centre of the screen is therefore not sufficient.

6.4 Crosstalk thresholds

Based on [b-Wang], [b-Seuntiens] and [b-Skala], a maximum of approximately 2 per cent crosstalk is recommended. Higher values of crosstalk become visible and influence perception. At this point, the crosstalk can change the results of a subjective experiment.

Based on [b-Chen], [b-Hanazato] and [b-Kooi], at 5 per cent to 6 per cent crosstalk becomes sufficient to cause visual discomfort or impact visual quality. At this point, the crosstalk may render the experiment invalid.

The various crosstalk measurement techniques differ. Therefore, this threshold can only be an indication. Due to differences between measurement techniques, alternative thresholds may be more appropriate for some techniques recommended in [b-IDMS1]. Depending on the 3D display technology, crosstalk may depend on several factors and further analysis on combined impact may be required [b-Tourancheau].

7 3D display environment

7.1 Impact of overall illumination on visual comfort zone

The overall illumination includes both the illumination coming from the display and from the ambient room illumination. For information on how to measure illumination, see clause 6.1. The overall illumination is measured at the position of the eye and pointed toward the display. It is reported that an overall illumination of at least 30 cd/m^2 is desirable [b-Patterson]. This allows the pupil to reach a diameter of about 2.5 mm, which corresponds to a sufficiently large depth of field (0.3 diopters [b-Howard]). Lower overall illumination will reduce the depth of field and thus the visual comfort zone. For consequences on visual comfort, see [ITU-T P.916].

7.2 Distance between display and wall

Care should be taken regarding the interaction between the real-world environment and the virtually displayed 3D scene. In particular, objects displayed with uncrossed disparity (behind the screen) may interfere with real objects behind the display, such as lighting installations and walls. This may have an impact on the ability of observers to feel immersed in the 3D effect.

7.3 Ambient lighting

Undesirable interactions between lights and the display system must be avoided. Examples include:

- Ambient lights should be placed to minimize reflections on the screen as seen by the position of the viewer;
- Frequency interactions between the display and lighting must be avoided. The ambient lighting should either produce a constant illumination or have a high frequency (e.g., high frequency electronic ballasts for fluorescent tubes);
- Ambient lighting behind the 3D display should not shine directly at the viewer.

Appendix I

Perceptual 3D video comparison of various 3D display monitors

(This appendix does not form an integral part of this Recommendation.)

Using various 3D display monitors, subjective tests were performed to understand the relationship between subjective scores of the 3D display monitors. The Nantes-Madrid 3D Stereoscopic Sequences Part 1-Database Coding and Spatial Degradations 1 (NAMA3DS1-COSPAD1) [b-NAMA] was used for the experiments. It contains ten source video sequences or source reference circuits (SRCs) with eleven hypothetical reference conditions (HRC). The ITU-T H.264/advanced video coding (AVC) encoder with three quantization parameters (QPs) (32, 38, 44) and JPEG 2000 (JP2) still image coder with four bitrates (2, 8, 16, 32 Mbps) were used to generate coding impairments. Rescaling (↓4 downsampling i.e., downscaling by a factor of 4) and image sharpening through edge enhancement processes were also included. Table I.1 shows a description of the 3D displays used in the experiments. Table I.2 shows the correlations between the subjective scores obtained by the 3D displays. As can be seen in the tables, all the 3D displays showed high correlations with the other 3D displays.

Table I.1 – Specifications of 3D displays

Index	Diagonal (inch)	Resolution	3D monitor type
1	46	1920x1080	Polarized glass
2	47	1920x1080	SG
3	27	1920x1080	Film-type patterned retarder (FPR)
4	23	1920x1080	FPR
5	17.3	1920x1080	SG
6	15.6	1920x1080	Auto-stereoscopic

Table I.2 – Correlation table between each pair of the 3D displays

Index	1	2	3	4	5	6
1	1	0.961	0.981	0.977	0.971	0.960
2	0.961	1	0.968	0.952	0.940	0.941
3	0.981	0.968	1	0.981	0.963	0.956
4	0.977	0.952	0.981	1	0.960	0.952
5	0.971	0.940	0.963	0.960	1	0.965
6	0.960	0.941	0.956	0.952	0.965	1

Appendix II

Perceptual 3D video quality of TB and SBS formats with different 3D displays

(This appendix does not form an integral part of this Recommendation.)

Currently, most 3D programmes are encoded using the top-bottom (TB) and side-by-side (SBS) video formats. The perceptual 3D video quality of two 3D-display monitors (polarized glass and shutter glass) is compared when 3D video sequences are encoded in the SBS and TB formats.

Table II.1 provides a description of the two 3D-display monitors. Ten source video sequences or SRCs were chosen with consideration of spatial and temporal information. The 3D video sequences were encoded using ITU-T H.264 at six bitrates (2, 3, 4.5, 5.5, 7.5 and 15 Mbps). Subjective testing was performed for each display using 24 non-expert viewers after vision tests.

Table II.1 – Specifications of 3D display monitors

Display	Type	3D type	Diagonal size	Resolution
1	Laptop	SG (Active)	17.3”	1920x1080
2	TV	FPR (Passive)	55”	1920x1080

Figures II.1 and II.2 show scatter plots of the mean opinion score (MOS) values for the TB and SBS formats. The correlation coefficients between the two display monitors were 0.951 (TB format) and 0.957 (SBS format). The experimental results show that the perceptual video quality of the two 3D display monitors correlated highly. The Nantes-Madrid 3D Stereoscopic Sequences Part 1-Database Coding and Spatial Degradations 1 (NAMA3DS1-COSPAD1) was used for the experiments [b-NAMA].

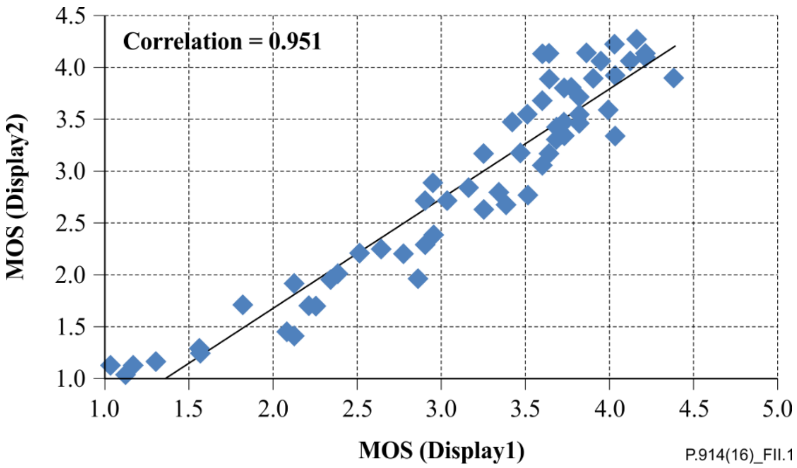

Figure II.1 – Scatter plot (TB format)

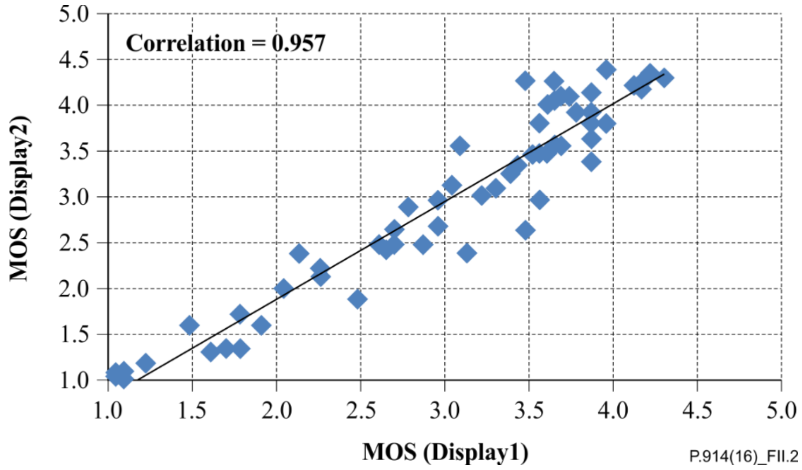

Figure II.2 – Scatter plot (SBS format)

Appendix III

Open questions

(This appendix does not form an integral part of this Recommendation.)

Because of the problems mentioned in clause 6.2, a proposed alternative approach to characterize the impact of the display crosstalk on perceived 3D visual experience is the use of subjective testing where participants are asked to perform a disparity discrimination task, with the idea that the accuracy of the subjects' responses will be negatively impacted by the display crosstalk. Further experiments are necessary to examine the merits of such an approach, how it compares to physical measurements and how such task recognition accuracy may be considered as a potential criterion for 3D display selection.

Threshold values for the crosstalk methods described in [b-IDMS1] should be researched.

Research is needed into the interaction between the real-world environment and the virtually displayed scene, particularly with regard to the distance between the display and the wall behind the monitor.

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