IEC TR 62977-5-2

Edition 1.0 2021-03

TECHNICAL REPORT

colour
inside

Electronic displays –
Part 5-2: Visual assessment – Colour discrimination according to viewing direction

IEC TR 62977-5-2:2021-03(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.120

ISBN 978-2-8322-9514-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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The text of this Technical Report is based on the following documents:

Draft	Report on voting
110/1227/DTR	110/1251A/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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INTRODUCTION

Current display measurement standards use mainly simple patterns for physical measurement methods to characterize display performance. Recent studies have introduced multiple colour test patterns to simulate real images based on physical measurements. Such types of physical measurements are commonly used and are an essential method of the industry. Often, humans can perceive a structural similarity [1][1] as much as physical factors (colour, luminance, etc.). This document describes a method of structural sensitivity assessment dependent on the viewing direction, interpretation of assessment results, and correlation between assessment results and physical measurements. This correlation value can be used as the basis for determining one aspect of the viewing direction range of a display, which has relevance from a visual quality point of view. However, it should be noted that several characteristics (e.g. contrast ratio, resolution, and colour shift) are simultaneously changing in the assessment of the viewing direction.

This visual assessment approach has the benefit of obtaining direct human response to variations for any given task. However, it can be challenging with this approach to get reproducible experimental results due to different colour matching functions (CMFs), differences in observer experience, observer fatigue, attitudes toward experiments, human adaptation to different experimental environments (including illumination conditions, surround, or other environmental factors), content-dependent differences, and other variables. Therefore, the uncertainty for these visual assessment methods can be higher compared to instrumentation-based evaluation methods. Accordingly, this document should be seen as a limited constrained model to help understand some of the various human responses to the experiment. It can be used as an indicator of such response and to provide a framework to guide the acquisition of performance data by way of reliable instrumentation-based measurement methods.

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[1] Numbers in square brackets refer to the Bibliography.

ELECTRONIC DISPLAYS –

Part 5-2: Visual assessment – Colour discrimination according to viewing direction

1 Scope

This part of IEC 62977, which is a Technical Report, describes the visual assessment method of the viewing direction characteristics of display devices. This document reviews the visual assessment of viewing direction by using special test patterns to estimate colour changes, image structure, and image luminance.

Experimental results are shown to reveal the effectiveness of this kind of visual assessment.

This method is a valuable tool for identifying image quality issues, but physical measurements will be used to confirm display performance specifications.

NOTE The visual assessment results will depend on the test pattern parameters and display setup conditions. As the viewing direction changes, characteristics such as contrast ratio, resolution, and device colour-shift simultaneously change in the perceived image.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
pixel
smallest encoded picture element in the input image

Note 1 to entry: Pixel is used as the unit of resolution of image sensor, image signal and display, respectively.

3.1.2
structural similarity
SS
measurement of the similarity between two images by comparison of the luminance, contrast and structure

Note 1 to entry: Refer to [1].

3.1.3
viewing direction

direction from which the display is viewed as measured from the normal using spherical-polar coordinates

3.2 Abbreviated terms

APL	Average picture level
CCT	Correlated colour temperature
CIE	Commission Internationale de L’Eclairage (International Commission on Ilumination)
CIELAB	CIE 1976 ($L^*a^*b^*$) colour space [2]
CMF	Colour matching function
CSF	Contrast sensitivity function
DFT	Discrete Fourier transform
DUT	Device under test
FF	Fill factor (of a dot)
HVS	Human visual system
JND	Just noticeable difference
LMD	Light measuring device
MSE	Mean squared error
PSNR	Peak-signal-to-noise ratio
SS	Structural similarity
TV	Television set
ZF	Zooming factor
$\Delta E^*_{\mathrm{ab,76}}$	CIE 1976 ($L^*a^*b^*$) colour difference
ΔE^*_{00}	CIE 2000 colour difference [3]

4 Introduction to visual assessment

Traditional physical measurements to describe the properties of displays have been used on a regular basis. Sometimes, visual assessment methods have been introduced due to cost concerns, limitations of physical measurements, or to verify the effectiveness of physical methods with regard to HVS.

As typical examples, IEC has published a number of visual assessment methods (IEC 62629-13-1 [32], IEC 61747-20-3 [33], IEC 62341-6-2 [34] and IEC 61988-2-4 [35]). These documents focus on the qualities of images (perceptual screen resolution, cross-talk, colour gradation, half-luminance viewing angle, 2D-artefacts, and 3D-ghosts), and defects (subpixel-, mura- and line-defects) of displays. Such methods and the colour- and greyscale inversions under varying viewing directions were also the focus of IDMS:2012 [4], Chapter 4.

In broadcasting technology, for example, visual image quality assessments for video clips are popularly used. Many technical parameters, test environments, test methods and datasets used in image quality assessments are described in standards and recommendations issued by the International Telecommunication Union (ITU) [5] and the European Broadcasting Union (EBU) [6].

Usually the image quality of a display depends on the viewing direction. To describe the dependence in the viewing direction, the conventional physical measuring method [7] is well-established in industry. It is stable, robust and can uniquely determine the viewing direction range using the colour difference metric. But the viewing direction range is a complex feature and determined by multiple factors that vary simultaneously, for example luminance, tone rendering, and colour shift. It is a challenge to weigh these factors into a single viewing direction range metric. Another challenge is that measurements use aperture colours (colours in a small portion of the viewing field) which do not take into account spatial filtering in the HVS. To include the CSF of the HVS, the S-CIELAB method has been used [8].

The advantage of physical measurements is that CIELAB with ΔE^*_{00} takes chromatic, luminance adaptation and the uniform JND metric into account for the representative CIE-CMF. However, human colour perception is a very complex process. It depends on many factors, such as chromatic and luminance adaptation, lateral inhibition of ganglion cells, contrast sensitivity, simultaneous contrast, adaptation on local image features and subjectivity of colour perception (human colour experiences) [9].

An imaging LMD with ΔE^*_{00} metric can provide a stable and objective measurement result for the representative CIE-CMF. However, it cannot represent the entire colour perception of observers and observer variabilities. To achieve more precise perception an imaging LMD can be combined with a vision model, but it is not easy to describe complex processes of human colour perception with a few mathematical functions. As a concern, the physical measurement does not fully reflect the HVS sensations and abilities. A colour difference between two colours with physically constant colour differences can be perceived differently by humans, affected according to changes in various conditions (e.g. object size, shape, ambient brightness, etc.) [9]. In particular, colour discrimination between two coloured objects within the same viewing direction is not included in the physical measurement. Colour discrimination is the ability of human perception to distinguish two different coloured objects. It can also be expressed in terms of a colour difference between two coloured objects within the same viewing direction such as ΔE^*_{00}. In conventional physical measurement, there are only the measurement methods of colour and luminance differences between the normal-axis (as reference) and the other viewing direction (see Figure 1).

Recently, it was verified that the SS [1] is a meaningful criterion of image quality. SS was developed to improve on conventional methods such as peak signal-to-noise ratio (PSNR) and mean squared error (MSE). SS is a perception-based model that considers image degradation as perceived change in structural information. It is the reproduction ability of the image detail and shape. Thus, SS can be an additional important feature beyond the conventional measurement of the colour and luminance characteristic. Changing the viewing direction can diminish the shape of the object and the image details. One of the functional components of the SS is that two neighbouring colours could be discernible to each other.

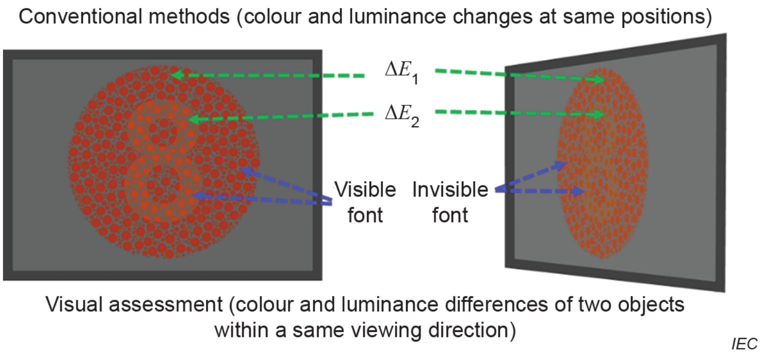

Figure 1 – Comparison between the proposed visual assessment and the conventional physical measurement

The conceptual Figure 1 shows the differences between the conventional physical measurement and the new visual assessment for the colour discrimination under varying viewing directions. The conventional method describes well the viewing direction-dependent characteristic in relation to the normal axis (IEC TS 62977-3-1 [7]). It checks the colour constancy between two viewing directions. With respect to the viewer, it is also important to get visual information within a same viewing direction.

Another meaning of the visual assessment method in comparison to the physical measurement is with respect to observers. The colourimetric value of the measuring instrument is evaluated by the 1931 CIE-CMF, which is approximately derived from the average sensitivities of a number of observers. The effectiveness of this CMF has been extensively studied and there has been a lot of demand for improvements to this CMF. Although 1931 CIE-CMF had to be supplemented, continuous use of this CMF was considered more efficient than revision [10], [11]. Recently, CIE published the observer's LMS-cone sensitivities by age and angle of view [11]. At a constant viewing angle, the cone sensitivities slowly shift towards the long wavelength. The shift is about 5 nm between 10 years and 60 years of age. This shift is accelerated from the age of 70 with 10 nm and more. Thus, it is preferred to supplement the physical measurement method with the visual assessment method because there is a limit to represent the change of the spectral sensitivity of different observers by the mean value derived CMF. Such observer variation would be roughly treated as a statistical plot of observer ratings by the visual assessment method.

Usually the colour perception of humans is also influenced by geometric changes of object shapes and spatial frequency content which happen with a change of the viewing direction [9]. It would be helpful for visual assessment, if the proposed method would be added.

Therefore, the visual assessment method of this document is a supplemental method for the conventional method.

5 Standard measuring equipment and coordinate system

5.1 Light measuring devices

Light measuring devices (LMDs) for the initial setup of the visual assessment considered in IEC 62977-2-1:2021, 5.3, are used [13]. An LMD or imaging LMD can be used in order to measure the colour differences of the test pattern, the correlated colour temperature and peak luminance of a display white.

NOTE A vision model of an imaging LMD depends on products. Here, imaging LMDs are calibrated by XYZ values.

5.2 Viewing direction coordinate system

The viewing direction coordinate system for LMDs specified in IEC 62977-2-1:2021, 5.6 is used, and is represented in Figure 2.

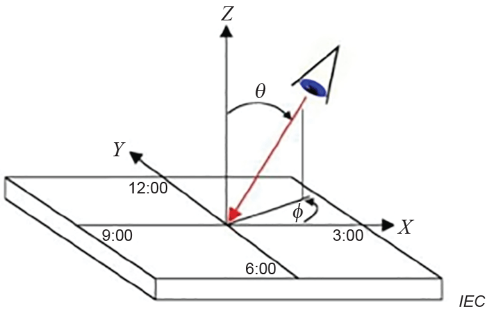

Figure 2 – Definition of viewing directions by the spherical angles of θ and φ

For visual assessment in the horizontal direction, the observer can be positioned as shown in Figure 3. The observing layout for the vertical viewing direction can also be used for the horizontal layout with a rotating the screen at 90° to construct a simple test equipment with only horizontal tilt, or by tilting the screen vertically at the normal viewing direction.

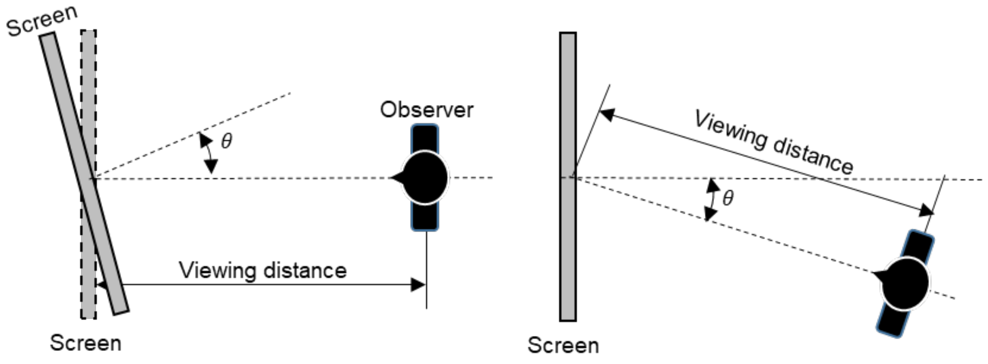

Figure 3 – Layout for horizontal viewing direction

The suggested ranges of the direction (θ and φ) are shown in Table 1 for DUTs in living rooms [7].

Table 1 – Measurement directions for DUTs in living rooms

	θ (degree)	φ (degree)
Horizontal	0, ±15, ±30, ±45, ±60	0
Vertical	0, ±15, ±30	90
Diagonal	45	45, 90, 135, 225, 270 and 315

NOTE Table 1 is consistent with IEC TS 62977-3-1:2019, Table 1 [7]. If needed, it can be adjusted by test organizations for their purposes.

6 Test patterns

6.1 Geometrical construction

The geometrical structures and dimensions of the test patterns are shown in Figure 4. The first rectangular colour patch type (Figure 4a)) is designed for the optical measurement by the LMD. The second inside font (number or alphabet) type (Figure 4b)) is used for the visual assessment. All sizes are specified by factors of the display screen height (H), and the size of the inside stimuli is 1/18 × H (font height). Therefore, the font width is defined by the notation of the used font format. The inside font has a 2° viewing angle as the default for the observer. The viewing angle is kept at 2°.