

Recommendation **ITU-T F.780.6 (03/2025)**

SERIES F: Non-telephone telecommunication services

Multimedia services

Requirements for colourimetry for telemedicine systems using ultra-high definition imaging

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Recommendation ITU-T F.780.6

Requirements for colourimetry for telemedicine systems using ultra-high definition imaging

Summary

Recommendation ITU-T F.780.6 describes the requirements for the use of colour and colourimetry for telemedicine systems using ultra-high definition imaging.

It also outlines the requirements for the light source and test object colours, the camera and transmission, the viewing conditions and display, as well as the overall characteristics of the telemedicine system.

It includes annexes on test colours for medical imaging equipment, measurement methods for colour capturing accuracy of cameras, and measurement method of colour reproducibility of electronic displays.

History*

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T F.780.6	2025-03-16	21	11.1002/1000/16246

Keywords

Colourimetry, digital imaging, telemedicine, ultra-high definition.

* To access the Recommendation, type the URL <https://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID.

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Introduction

Digital imaging is widely used in telemedicine, including surgery and even by pathologists for the creation of static images using microscope-dedicated optical cameras. Recently, this practice has gained even more urgency as many healthcare practices have to be done remotely, due to COVID-19. Such digital imaging for telemedicine is sometimes done using smartphones.

It is clear that robust diagnosis relies upon satisfactory cross-media colour reproduction between physical targets and digital images displayed on different displays and observed under disparate viewing conditions. For this reason, standardization on the use of colour in medical imaging is necessary.

The digital imaging and communications in medicine (DICOM) [b-ISO 12052] grayscale standard display function (GSDF) was developed to provide an objective, quantitative mechanism for mapping digital image values into a given range of luminance values in order to produce better visual consistency in the way images appear on diverse display devices [b-DICOM]. The DICOM GSDF is intended for use with grayscale images, such as x-ray images, MRI, CT, and ultrasound. As such, therefore, DICOM GSDF is not suitable as a standard to be used for ultra-high definition (UHD) medical imaging.

However, there seems to be so far no agreed upon standard for describing the way colour is used for visualization of medical images or how calibration and quality assurance of displays for medical images need to be done.

It is especially important for UHD imaging to have such a standard, as UHD imaging may be used for various areas, including endoscopic and open surgery, diagnosis and education.

Recommendation ITU-T F.780.6

Requirements for colourimetry for telemedicine systems using ultra-high definition imaging

1 Scope

This Recommendation describes the requirements for the use of colour and colourimetry for telemedicine systems using ultra-high definition imaging. It also outlines the requirements for the light source and test object colours, the camera and transmission, the viewing conditions and display as well as the overall characteristics of the telemedicine system.

It includes annexes on test colours for medical imaging equipment, measurement methods for colour capturing accuracy of cameras, and measurement method of colour reproducibility of electronic displays.

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 F.780.1](#)] Recommendation ITU-T F.780.1 (V3) (2023), *Framework for telemedicine systems using ultra-high definition imaging*.
- [ITU-R BT.2020] Recommendation ITU-R BT.2020 (2015), *Parameter values for ultra-high definition television systems for production and international programme exchange*.
- [ISO-9241-305] ISO 9241-305 (2008), *Ergonomics of human-system interaction – Part 305: Optical laboratory test methods for electronic visual displays*.
- [ISO 12646] ISO 12646 (2015), *Graphic technology – Displays for colour proofing – Characteristics*.
- [ISO/CIE 11664-4] ISO 11664-4:2019, *Colorimetry – Part 4: CIE 1976 L*a*b* Colour space*.
- [ISO/TS 17321-4] ISO/TS 17321-4 (2022), *Graphic technology and photography – Colour characterization of digital still cameras (DSCs) – Part 4: Programmable light emission system*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 chromaticity [b-ISO/CIE 11664-2]: Property of a colour stimulus defined by its chromaticity coordinates, or by its dominant or complementary wavelength and purity taken together.

3.1.2 colour rendering [b-ISO/CIE 11664-2]: Effect of an illuminant on the perceived colour of objects by conscious or subconscious comparison with their perceived colour under a reference illuminant.

3.1.3 colour rendering index [b-ISO/CIE 11664-2]: Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

3.1.4 correlated colour temperature [b-ISO/CIE 11664-2]: Temperature of a Planckian radiator having the chromaticity nearest the chromaticity associated with the given spectral distribution on a modified 1976 UCS diagram where u' , $(2/3)v'$ are the coordinates of the Planckian locus and the test stimulus.

3.1.5 illuminance [b-ISO/CIE 11664-2]: Density of incident luminous flux with respect to area at a point on a real or imaginary surface.

$$E_v = \frac{d\Phi_v}{dA}$$

where Φ_v is luminous flux and A is the area on which the luminous flux is incident.

3.1.6 illuminant [b-ISO/CIE 11664-2]: Radiation with a relative spectral power distribution defined over the wavelength range that influences object-colour perception.

3.1.7 luminance [b-ISO/CIE 11664-2]: Density of luminous intensity with respect to projected area in a specified direction at a specified point on a real or imaginary surface.

$$L_v = \frac{dl_v}{dA \cos \alpha}$$

where l_v is luminous intensity, A is area and α is the angle between the normal to the surface at the specified point and the specified direction.

3.1.8 luminous reflectance [b-ISO 3664]: Ratio of the luminous flux reflected from a surface to the luminous flux incident on the surface.

3.1.9 relative spectral power distribution [b-ISO 3664]: Ratio of the spectral power distribution of a source or illuminant to a fixed reference value.

NOTE – The fixed reference value can be an average value, a maximum value or an arbitrarily chosen value of this distribution

3.1.10 ultra-high definition [ITU-T F.780.1]: A video format of digital display and camera in which the horizontal screen resolution is on the order of over 4 000 pixels.

3.1.11 ultra-high definition imaging [ITU-T F.780.1]: Video imaging using system parameters of an ultra-high definition television (UHDTV) as defined by [ITU-R BT.2020].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 CIE 1931 standard colorimetric system: The first defined quantitative links between distributions of wavelengths in the electromagnetic visible spectrum, and physiologically perceived colours in human colour vision.

3.2.2 colour gamut: A range of colours within the spectrum of colours, or a colour space, that can be reproduced on an output device.

3.2.3 correlated colour temperature: A one-dimensional metric that aims to quantify the perceived visual quality of nominal white light sources.

3.2.4 delta E (ΔE): The difference between two colours designated as two points in the colour space as defined by CIE. ΔE^*_{ab} between two colour stimuli is calculated as the Euclidean distance between the points representing them in the space:

$$\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{\frac{1}{2}}$$

NOTE – $\Delta L^* = (L_1^* - L_0^*)$, etc.

3.2.5 out of gamut: A range of colours that cannot be reproduced within the colour space of the output device.

NOTE – Perceptual rendering intent is a good choice for keeping images realistic when there is a significant amount of out of gamut colours and it will help images avoid 'stair stepping' in the middle of a gradient. The other commonly used rendering intent is relative colorimetric. This rendering intent maps white of the input colour space to the white of the output colour space and then will reproduce in-gamut colours exactly. Out of gamut colours will be shifted to the next available colour in the output colour space. This option is the most accurate, however it can result in stair stepping in areas of gradient. Since we are looking for pathology and changes from the normal fundus photographs, having colour relationships preserved is probably more useful than having the exact colour represented.

3.2.6 International Color Consortium (ICC) profile: A set of data that characterizes a colour input or output device, or a colour space, according to standards promulgated by the International Color Consortium (ICC).

NOTE – Profiles describe the colour attributes of a particular device or viewing requirement by defining a mapping between the device source or target colour space and a profile connection space (PCS).

3.2.7 profile connection space: The International Commission on Illumination (CIE) colourimetry which, in the case of the perceptual rendering intent, will produce the desired colour appearance if rendered on a reference imaging media and viewed in a reference viewing environment.

NOTE – It is one of two device-independent measuring systems for describing colour based on human vision, and is usually determined automatically by the source profile. Typically, end users have little direct interaction with the PCS.

3.2.8 programmable light emission system: A programmable self-emissive colour target.

3.2.9 self-emissive colour target: Colour target with self-emissive devices.

3.2.10 metamerism: The phenomenon in which two colours with different spectral distributions appear to be the same colour under certain lighting conditions.

3.2.11 uniform chromaticity scale: See chromaticity.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CCAC	Measurement methods for Colour Capturing Accuracy of Cameras
CCT	Correlated Colour Temperature
CIE	International Commission on Illumination
CRI	Colour rendering index
DICOM	The Digital Imaging and Communications in Medicine
FOV	Field Of View
GSDF	Grayscale Standard Display Function
OETF	Opto-Electronic Transfer Function
PCS	Profile Connection Space
PLES	Programmable Light Emission System
RGB	Red Green Blue
SPD	Spectral Power Distribution
UCS	Uniform Chromaticity Scale

UHD	Ultra-High Definition
UHDTV	Ultra-High Definition Television
WCG	Wide colour gamut

5 Conventions

In this Recommendation:

- 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 "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term does not imply that the vendor's implementation must provide the option, nor that the feature can be optionally enabled by the network operator/service provider. Rather, it means that the vendor may optionally provide the feature and still claim conformance with this Recommendation.

6 Background

The following are the reasons for the need of this Recommendation:

- Necessity of telemedicine due to the spread of COVID-19 (reduction of contact opportunities and consultation hours).
- Improvement of digital technology such as the realization of high-speed communication of UHD images by 2K, 4K, 8K as well as over 5G.
- Progress in digitization of medical information: e.g., the difference in device colour reproducibility, integration of colour information, database, introduction of AI.
- Progress of aging societies that requires the improvement of educational efficiency for medical staff as well as the remote medical guidance using educational images.

The diagram in Figure 6-1 describes the typical situation where colourimetry becomes crucial in telemedicine. There are at least two variables at the source to be considered at the source of imaging: the light source and the camera (system) or its equivalent.

These variables, if uncontrolled, will result in different characteristics of images, which will complicate the decision process of diagnosing and other medical practices in the telemedicine scenario.

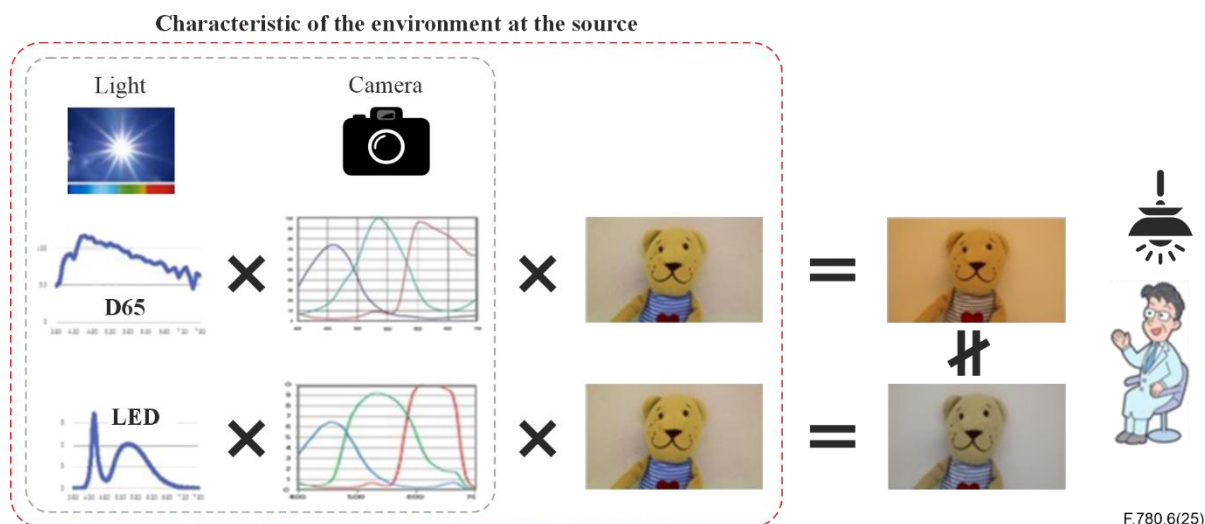


Figure 6-1 – Description of the problem

7 Conditions for high-fidelity colour reproduction

The overview of the framework is shown in Figure 7-1. A light source illuminates objects and the reflected light is input to the camera as scene light. Requirements for the light source and test object colours are described in clauses 7.1 and 7.2, respectively. The scene light is captured by the camera and converted to electronic signals for transmission and display. Requirements for the camera and transmission are described in clauses 7.3 and 7.4, respectively. The transmitted signals are input to the display, which reproduces the scene light as displayed light. The colour appearance of the displayed light is affected by viewing conditions. Requirements for the viewing conditions and display are described in clauses 7.5 and 7.6, respectively. Requirements for the overall characteristics of the system consisting of the camera, transmission and display are described in clause 7.7.

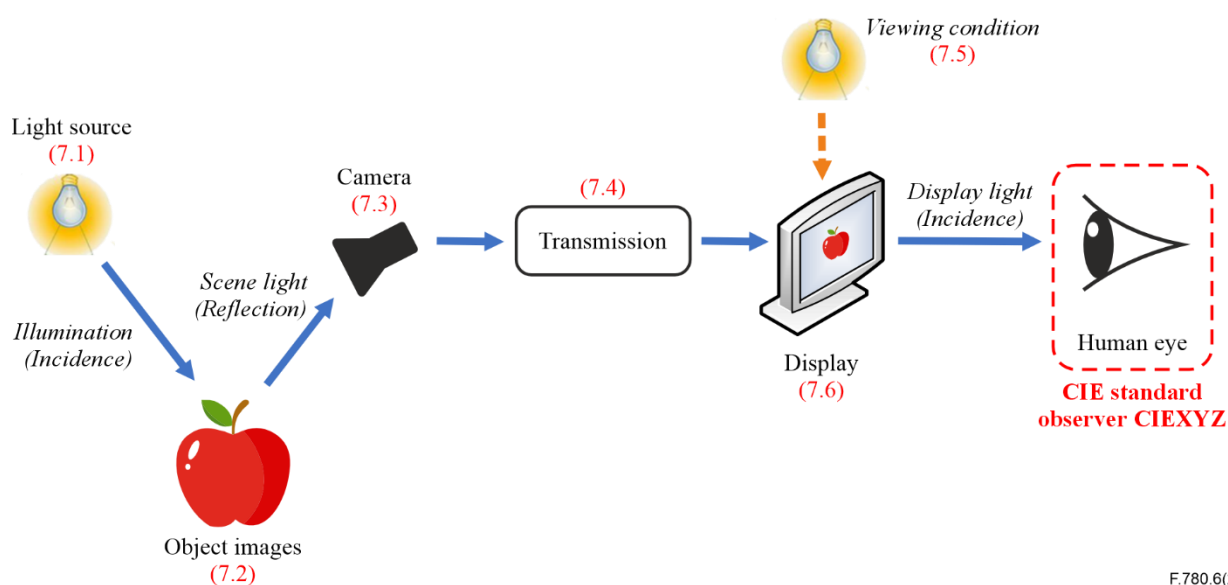


Figure 7-1 – Overview of the relevant system

7.1 Illumination

Illumination for ultra-high definition (UHD) and high colour fidelity medical imaging is desired to satisfy the following conditions:

- Correlated colour temperature (CCT): 4000 to 5300K.

- Colour rendering index (CRI): Ra is 90 or over, and R9 is 80 or over.

7.2 Test colours

Test colours for medical imaging equipment are shown in Annex A. The test colours should be used for measurement, calibration, etc. of colour reproducibility of medical imaging equipment.

7.3 Colour reproduction of camera

7.3.1 Measurement method

The measurement method for colour reproducibility of a camera is desired to use the Measurement methods for colour capturing accuracy of cameras (CCAC) described in Annex B.

Note that this method measures the colour reproducibility of camera output signals in the linear red green blue (RGB) signal domain or before applying any "gamma pre-correction" (opto-electronic transfer function (OETF)). The OETF will be described in clause 7.4.1.

7.3.2 Colour reproduction error

Colour reproduction error of camera for ultra-high definition and high colour fidelity medical imaging should be assessed by colour difference ΔE^*_{ab} .

The ΔE^*_{ab} should be measured using the method described in clause 7.3.1, for the test colours described in clause 7.2, under the illumination described in clause 7.1.

The resultant ΔE^*_{ab} is desired to satisfy the following.

ΔE^*_{ab} is 5 or less.

The formula for calculating ΔE recommended in this document is [ISO/CIE 11664-4] (denoted ΔE^*_{ab}), as calculated by:

$$\Delta E^*_{ab} = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

where:

L_1, a_1, b_1 are Lab values of each test colour illuminated by the illumination used in the measurement;

L_2, a_2, b_2 are Lab values of the linear camera output for the test colour illuminated by the illumination used in the measurement.

7.4 Transmission of image signals

7.4.1 Signal format of camera output

The signal format of the camera output for display and transmission should follow [ITU-R BT.2020]. Especially, the system colourimetry is shown in Table 1, and "gamma pre-correction", or the non-linear opto-electronic transfer function (OETF) is shown in Table 2. For $Y'C'_B C'_R$ signals, etc., see [ITU-R BT.2020].

Table 1 – System colourimetry of [ITU-R BT.2020]

Parameter	Values		
Opto-electronic transfer characteristics before non-linear pre-correction	Assumed linear ⁽¹⁾		
Primary colours and reference white	Chromaticity coordinates (CIE, 1931)	X	y
	Red primary (R)	0.708	0.292
	Green primary (G)	0.170	0.797
	Blue primary (B)	0.131	0.046
	Reference white (D65)	0.3127	0.3290
⁽¹⁾ Picture information can be linearly indicated by the tristimulus values of RGB in the range of 0-1.			

Table 2 – Non-linear opto-electronic transfer function (OETF) of [ITU-R BT.2020]

Parameter	Values	
Signal format	$R'G'B'$	
	Constant luminance $Y'_C C'_{BC} C'_{RC}$	Non-constant luminance $Y'_C C'_{BC} C'_R$
Non-linear transfer function	$E' = \begin{cases} 4.5E, & 0 \leq E < \beta \\ \alpha E^{0.45} - (\alpha - 1), & \beta \leq E \leq 1 \end{cases}$ <p>where E is the voltage normalized by the reference white level and proportional to the implicit light intensity that would be detected with a reference camera colour channel R, G, B; E' is the resulting non-linear signal.</p> <p>α and β are the solutions to the following simultaneous equations:</p> $\begin{cases} 4.5\beta = \alpha\beta^{0.45} - \alpha + 1 & (1) \\ 4.5 = 0.45\alpha\beta^{-0.55} & (2) \end{cases}$ <p>The simultaneous equations provide the required condition to connect the two curve segments smoothly and yield $\alpha = 1.09929682680944\dots$ and $\beta = 0.018053968510807\dots$. For practical purposes, the following values can be used:</p> <p>$\alpha = 1.099$ and $\beta = 0.018$ for 10-bit systems $\alpha = 1.0993$ and $\beta = 0.0181$ for 12-bit systems</p>	

Note that the reference gamma characteristic of the reference monitor described in [b-ITU-R BT.1886] is not the inverse function of the OETF in Table 2, so it is not suitable for use in displays for high-fidelity colour reproduction.

7.4.2 Coding, transmission and decoding of image signals

As for coding, transmission and decoding of ultra-high definition and high colour fidelity image signals, it is recommended to follow the requirements described in [ITU-T F.780.1] clause 7.2.

7.5 Viewing conditions

Viewing conditions for ultra-high definition and high colour fidelity medical images are desired to satisfy Table 3.

These conditions mainly assume medical examination room including telemedicine, or an area away from surgical lights in an operating room.

Table 3 – Viewing conditions

Parameter	Values
Room illumination	
Correlated colour temperature (CCT)	4000 to 5300 K
Colour rendering index (CRI): Ra	90 or over
R9	80 or over
Horizontal illuminance near the front of the screen of image display	500 to 1500 lux
Display screen angle	Vertical to approximately 15 degrees tilted
Display installation location	Avoid direct reflections of light from any light source onto viewers, on the display screen
Peak luminance ⁽¹⁾ of displayed image	100 to 500 cd/m ²
Display contrast ratio	0.02 or less
Ratio of luminance of surround ⁽²⁾ behind the display to the peak luminance	Approximately 10 to 20%
⁽¹⁾ Peak luminance should be adjusted according to the room illumination. ⁽²⁾ "Surround" is the area surrounding a display that can affect the adaptation of the eye, typically the wall or curtain behind the display.	

7.6 Colour reproduction of display

7.6.1 Measurement method

Measurement method of colour reproducibility of a display is described in Annex C.

The display input signal for this measurement should follow the signal format described in clause 7.4.1.

7.6.2 Colour reproduction error

Colour reproduction error of display for ultra-high definition and high colour fidelity medical imaging should also be assessed by colour difference ΔE^*_{ab} .

The reference display input signal for the measurement should have R'G'B' values in the signal format described in clause 7.4.1, for the test colours described in clause 7.2, under the illumination described in clause 7.1. The reference signal means the output of an ideal camera of [ITU-R BT.2020].

The ΔE^*_{ab} should be measured using the method described in clause 7.6.1, for the reference display input signals, under the viewing conditions described in clause 7.5.

The resultant ΔE^*_{ab} is desired to satisfy the following, over the field of view (FOV) of the 8K system of [ITU-R BT.2020].

ΔE^*_{ab} is 5 or less, in viewing angle range within ± 50 arc degrees horizontally and ± 33.7 arc degrees vertically, where ΔE^*_{ab} is calculated by:

$$\Delta E^*_{ab} = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$