TECHNICAL SPECIFICATION

ISO/TS 17321-4

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Graphic technology and photography — Colour characterization of digital still cameras (DSCs) —

Part 4:
Programmable light emission system

Technologie graphique et photographie — Caractérisation de la couleur des appareils photonumériques —

Partie 4: Système d'émission de lumière programmable

Reference number
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Foreword

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The committee responsible for this document is ISO/TC 42, *Photography*.

ISO 17321 consists of the following parts, under the general title *Graphic technology and photography — Colour characterization of digital still cameras (DSCs)*:

— *Part 1: Stimuli, metrology and test procedures*

— *Part 2: Considerations for determining scene analysis transforms* [Technical Report]

— *Part 4: Programmable light emission system* [Technical Specification]

The following parts are under preparation:

— *Part 3: User controls and readouts for scene-referred imaging applications* [Technical Report]

Introduction

There are many application areas such as medical imaging, cosmetics, e-commerce, sales catalogue, fine art reproduction and artistic archive where colorimetric image capture and colorimetric image reproduction are desired.

A high colour-fidelity imaging system using a black-and-white digital camera with rotary colour filters[12], and digital video cameras specified for colorimetric image capture[13], both of which have the same colour sensitivity as the colour matching functions defined by CIE 1931, are available today and fulfil these requirements. However, Reference [12] is a large-scale device which cannot be used to capture moving objects, and Reference [13] is dedicated to motion picture use.

Digital still cameras (DSCs) are often used as convenient devices for colorimetric image capture. Typically, DSCs do not have sensor sensitivities that are linear transforms of the colour matching functions defined by CIE 1931. It is, therefore, necessary that a matrix conversion from DSC-image-capture data to scene-colorimetric data be done to transform camera image data to estimates of scene colorimetric data. Although there are several methods to derive such a matrix, a method using colour targets is the most common when there is no data describing the DSC sensor spectral sensitivities.

Colour targets used to derive this conversion matrix are X-Rite ColorChecker Classic®[1)], X-Rite ColorChecker Digital SG®[2)] and others. These targets are reflective and so have a limited colour gamut compared to scenes where the subject includes highly saturated colours. In such a case, colour targets with highly saturated colours that can be used to derive the colour conversion matrix are very useful.

This part of ISO 17321 is applicable to light emitting devices such as inorganic or organic LEDs, quantum dots and laser diodes.

Note that although an integrating sphere is typically used, other mechanisms would also be applicable.

A procedure using a nonlinear Generalized Reduced Gradient (GRG) algorithm is specified in this part of ISO 17321 to minimize the square of the difference between a desired colour spectrum and the colour spectrum of the programmable light emission system.

This part of ISO 17321 will make use of a metric (S_{R2}), which provides a simple and direct means to calculate the colour difference between two spectra. This criterion (S_{R2}) will be used as a method to evaluate the performance of a programmable light emission system in terms of its ability to match a reference spectral power distribution. S_{R2} and CIEDE2000 metrics are both used for colour target evaluation.

This programmable light emission system can generate arbitrary illuminants such as D55, D65 and Illuminant A. Annex D describes evaluation metrics for light sources.

This system has several advantages as follows.

— An arbitrary smooth spectral power distribution similar to colour targets under a light source can be produced.

— Many colour metamers can be generated easily.

— Colours with different luminance, same hue and same saturation can be generated easily.

— Colours with different saturation, same luminance and same hue can be generated easily.

— Colours with high luminance can be produced.

— Reference colour target can be provided for display systems.

1) ColorChecker Classic® is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

2) ColorChecker Digital SG® is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.

Graphic technology and photography — Colour characterization of digital still cameras (DSCs) —

Part 4: Programmable light emission system

1 Scope

This part of ISO 17321 specifies requirements for a programmable light emission system to produce various spectral radiance distributions intended for DSC colour characterization applications.

NOTE 1 Evaluation metrics are described in this part of ISO 17321. These evaluations metrics are intended to provide "Figure of Merit (goodness)" relating to the ability of the device to produce arbitrary spectral power distributions.

NOTE 2 This part of ISO 17321 applies to a programmable light emission system composed of LEDs. However, it can be applied to light emitting devices such as quantum dots, organic LEDs, laser diodes and so forth.

NOTE 3 If spiky spectral reproduction is required, devices which have more spiky spectral light emission are intended to be used.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7589, *Photography — Illuminants for sensitometry — Specifications for daylight, incandescent tungsten and printer*

3 Terms and definitions

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

3.1
colour matching functions
tristimulus values (3.6) of monochromatic stimuli of equal radiant power

[SOURCE: CIE Publication 17.4, 845-03-23]

3.2
colour rendering index [R]
measure of the degree to which the psychophysical colour of an object illuminated by a 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

[SOURCE: CIE Publication No. 17.4:1987, 845-02-61]

3.3
digital still camera
DSC
device which incorporates an image sensor and which produces a digital signal representing a still picture

Note 1 to entry: A digital still camera is typically a portable, hand-held device. The digital signal is usually recorded on a removable memory, such as a solid-state memory card or magnetic disk.

[SOURCE: ISO 17321-1:2012, 3.2]

3.4
light-emitting diode
LED
semiconductor diode that emits non coherent optical radiation through stimulated emission resulting from the recombination electrons and photons, when excited by an electric current

[SOURCE: IEC 60050-521, 521-04-39]

3.5
raw DSC image data
image data produced by or internal to a DSC that has not been processed, except for A/D conversion and the following optional steps: linearization, dark current/frame subtraction, shading and sensitivity (flat field) correction, flare removal, white balancing (e.g. so the adopted white produces equal RGB values or no chrominance), missing colour pixel reconstruction (without colour transformations).

[SOURCE: ISO 17321-1:2012:3.4 — modified.]

3.6
tristimulus values
amount of the three reference colour stimuli, in a given trichromatic system, required to match the colour of the stimulus considered

Note 1 to entry: See *colour matching functions* (3.1).

[SOURCE: CIE Publication 17.4, 845-03-22]

4 Requirements

4.1 General

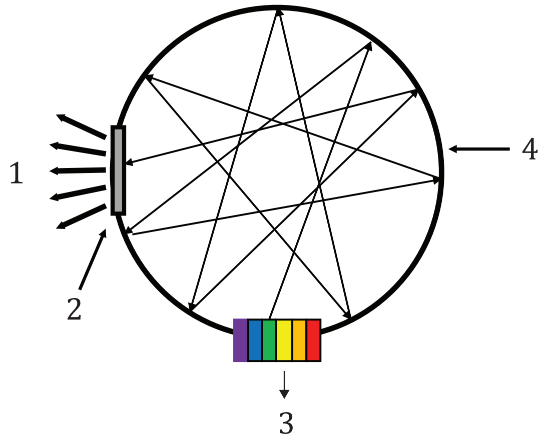
Figure 1 shows a section of an integrating sphere. This sphere is one method to ensure good spatial uniformity. Light emitting devices are placed at the bottom and an output window is placed on the side to allow the mixed light to be emitted. Annex A shows a typical LED-driving method.

NOTE 1 Integrating sphere is a typical case, but other mechanisms would be applicable.

There are many kinds of light emitting devices. However, this part of ISO 17321 describes a programmable light emission system using typical LEDs. Figure 2 shows typical spectral power distributions of a number of LEDs. These LEDs will be intensity-modulated and mixed (integrated) to produce a required spectral power distribution.

NOTE 2 Pulse width and interval modulation for intensity modulation is applicable.

NOTE 3 DSCs with automatic exposure control and automatic white balance cannot be applied for colour calibration using this system.



Key

1 uniform light emission on the output window

2 output window

3 light emitting device array

4 integrating sphere

Figure 1 — Schematic configuration of the programmable light emission system

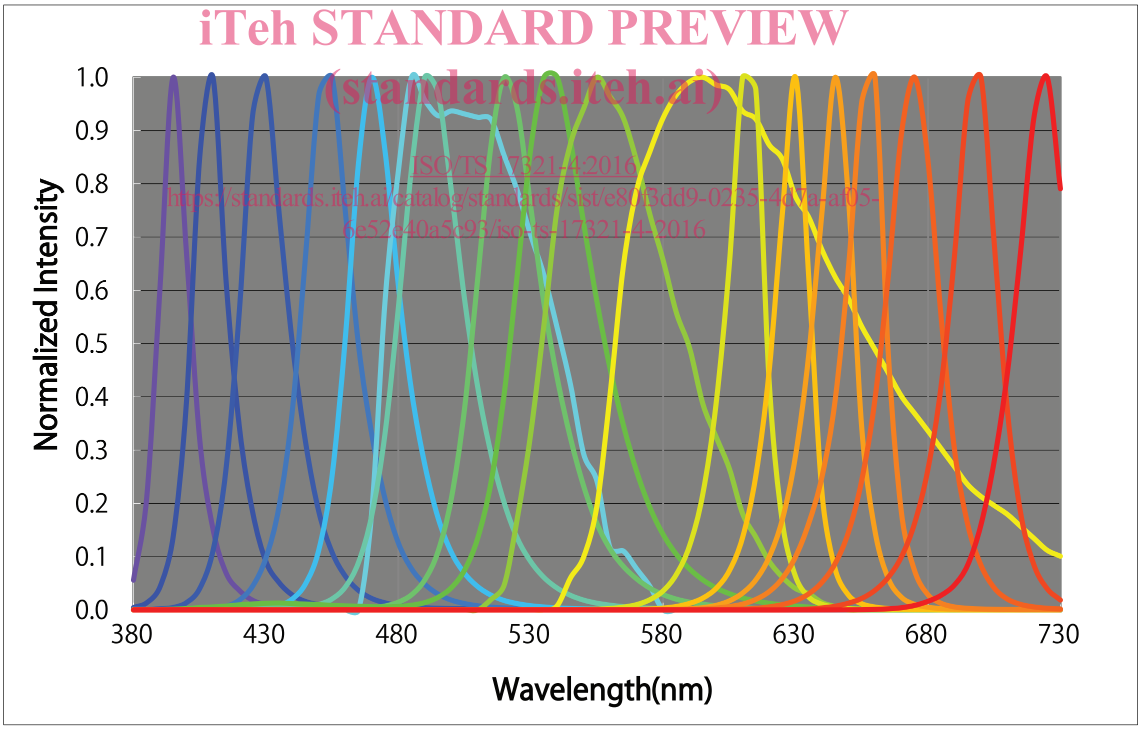


Figure 2 — Example of spectral power distributions for a chosen set of LEDs

4.2 Hardware requirements

4.2.1 General

This Clause is to describe a light emitting system for DSC colour characterization that uses an integrating sphere.

4.2.2 Operating condition

The light emitting system shall be designed to operate consistently under the following ranges.

NOTE "Temperature" condition was referred from ISO 12646.

— Temperature: 18 °C to 28 °C.

— Relative humidity: 15 % to 80 %.

4.2.3 Specifications of the system

4.2.3.1 Wavelength

The wavelength range over which the combined set of the light emissive devices is evaluated shall be 380 nm to 730 nm and should be 360 nm to 830 nm.

NOTE 1 The procedure to configure an LED array to achieve required spectral power distribution and chromaticity is described in Annex B.

NOTE 2 Evaluation metric (S_{R2L}) described in 4.2.3.2 can be applied to more extended range including IR/UV components when necessary.

4.2.3.2 Objective reference light source and calculated-reference light source

ISO 17321-1 describes that the spectral power distribution for illuminating the test target shall be photographic daylight, D55, as defined in ISO 7589. The standard illuminant D55 shall be used as a reference light source in this part of ISO 17321. A light source which is generated with a programmable light emission system is obtained by minimizing the S_{R2L} value in Formula (1). This optimization method is described in Annex B.

NOTE This programmable light emission system can generate other illuminants such as D65, A and so forth. D65 is used as the default illuminant for video uses.

4.2.3.2.1 Optimization procedure of a programmable light emission system to a reference light source

The mean of the squares of the differences between the objective reference and calculated light source spectral power distributions (S_{R2L}) is specified by:

$$S_{R2L} = \frac{\sum_{i=1}^{N} \left((L_{ri} - P_S E_{ci}) / Y_N Y_V \right)^2}{N} \tag{1}$$

$$Y_N = \sum_{i=1}^{N} L_{ri} \; / \; N \tag{2}$$

$$Y_V = \sum_{i=1}^{N} V_{ri} L_{ri} \; / \; Y_N \tag{3}$$

$$\sum_{i=1}^{N} V_{ri} = 1 \tag{4}$$

where

L_{ri} is the reference light source spectrum of the i-th wavelength;

E_{ci} is the spectrum of the i-th wavelength calculated for the programmable light emission system;

P_S is the scaling coefficient to adjust energy power level;

Y_N is the normalization factor on averaged power of the objective reference light source;

Y_V is the factor to compensate light source dependence using luminosity factor in case of relative light source value;

V_{ri} is the normalized-response of the the i-th wavelength derived from the luminosity function;

N is number of wavelength samples (i = 1, N).

The optimization procedure is as follows.

a) Measure the (absolute) spectral power distribution of each LED at its maximum intensity. This shall be done in the same way with the same units used, for example watts/(Sr × m^2 × nm), for each LED.

b) Using the optimization procedure described in Annex B, minimize the S_{R2L} value. This procedure calculates an LED intensity coefficient b_j of measured spectrum intensity ε_{ij} for j-th LED. A value of P_s is determined as follows. When one of the LEDs will be driven at its maximum coefficient, P_s is set to be the maximum value of b_j (j = 1, M). P_s is specified as the scaling coefficient for generating D55 illuminant or arbitrary light sources.

The following notations are used.

N is number of wavelength samples (i = 1, N).

M is number of LEDs.

$\boldsymbol{b}$ is intensity vector having b_j component (j = 1, M).

ε_{ij} is measured-spectral intensity of j-th LED (j = 1, M, i = 1, N).

c) Multiply each LED's measured spectral power distribution by the corresponding LED intensity coefficient b_j, and sum all of spectral power distributions to obtain E_{ci}.

d) Divide the summed spectral power distribution by P_s to obtain the calculated-spectral distribution E_{ci} of the programmable light emission system. E_{ci} is an output candidate spectrum distribution using the programmable light emission system.

$$E_{ci} = \sum_{j=1}^{M} b_j \varepsilon_{ij} \; / \; P_S \tag{5}$$

e) The calculated-reference light source spectrum distribution L'_{ri} corresponding to E_{ci} is obtained by dividing L_{ri} by P_s.

$$L'_{ri} = L_{ri} \; / \; P_S \tag{6}$$

L'_{ri} is used as the reference light source for optimization in 4.3.2 and 4.3.3.

The use of Y_V is optional. In cases where the luminosity function is applied independently (i.e. Y_V is not used), the value of Y_V should be set to 1,0.

NOTE 1 If normalization component L_{ri}/Y_N is not used, S_{R2L} values of illuminants with strong spectral peaks such as fluorescent lamps are smaller than those values of flat-like illuminants such as illuminant D55 and D65.

The maximum intensity of each light emitting device of the programmable light emission system can be determined beforehand from its hardware specification. It is recommended that these values are used as maximum constraint conditions for the optimization method described in Annex B in order to achieve the maximum intensity of each light emitting device. In this case, the intensity value is the maximum energy level of the corresponding light emitting device. In practice, the intensity values of light emitting devices should be set to lower levels than the maximum energy possible when reproducing spectra of objects colours. Intensity values for every light emitting devices for illuminant D55 can be determined using the optimization method with these constraint conditions.

NOTE 2 Exposure level and white balance setting for DSC can be achieved using light source power distribution above.

4.2.3.2.2 Evaluation for calculated light source

The evaluation for calculated light source of the programmable light emission system (S_{R2L}) is specified by Formula (1).

Annex F describes the calculation procedure of S_{R2L} if both relative spectral distribution of a reference light source and absolute spectral distribution of a measured light source are given.

4.2.3.3 Size, luminance, uniformity and angular characteristic

4.2.3.3.1 Output window

The output window (see Figure 1) shall be at least 50 mm in diameter.

4.2.3.3.2 Minimum luminance

The minimum luminance of the output window shall be greater than 40 cd/m^2 and should be greater than 80 cd/m^2 when simulating various light sources including fluorescent and LED light sources.

NOTE 80 cd/m^2 provides a luminance that allows an object illuminated by the source to be photographed satisfactorily at a distance of 50 cm using a DSC with an ISO speed of 200, an aperture of F5,6, a shutter speed of 1/30 s.

4.2.3.3.3 Uniformity

The luminance measured at the centre and at 8 points evenly spaced around the circumference of the output window at 45° intervals shall differ by no more than ±2 %. The luminance measurements are made normal to the plane of the output window at each measurement point.

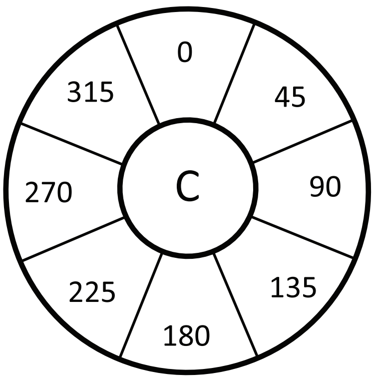


Figure 3 — Measurement points on the output window with every 45°

Figure 3 shows measurement points on the output window to calculate uniformity characteristics.

