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Colorimetry ~~-~~ — Part 6: CIEDE2000 colour-difference formula

~~FDIS stage~~

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~~A model manuscript of a draft International Standard (known as "The Rice Model") is available at~~

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by the International Commission on Illumination (CIE) in cooperation with ~~ISO/TC 274 "Light and Lighting".~~Technical Committee ISO/TC 274, *Light and lighting*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 139, *Paints and varnishes*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO/CIE 11664-6:2014), of which ~~has been technically revised.~~

it constitutes a minor revision. The ~~main~~ changes are as follows:

~~Update of~~ — normative references updated;

— previous Clause 3 split into Clauses 3 and 4;

— Clause 6: previous NOTE 1 changed to body text;

— minor editorial changes.

A list of all parts in the ISO/CIE 11664 series can be found on the ISO website and the CIE website.

Any feedback or questions on this document should be directed to the CIE Central Bureau or ~~to~~ the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The three-dimensional colour space produced by plotting CIE tristimulus values (*X*, *Y*, *Z*) in rectangular coordinates is not visually uniform~~, nor~~. Neither is the (*x*, *y*, *Y*) space nor the two-dimensional CIE (*x*, *y*) chromaticity diagram. Equal distances in these spaces and diagrams do not represent equally perceptible differences between colour stimuli. For this reason, the CIE has standardized two more-nearly uniform colour spaces (known as CIELAB and CIELUV~~}~~), whose coordinates are non-linear functions of *X*, *Y* and *Z*. Numerical values representing approximately the relative magnitude of colour differences can be described by simple Euclidean distances in these spaces or by more sophisticated colour-difference formulae that improve the correlation with the relative perceived size of differences. The purpose of this ~~International Standard~~document is to define one such formula, the CIEDE2000 formula. ~~The~~This document is based on CIE ~~Technical Report~~ 142~~-~~:2001.

The formula is an extension of the CIE 1976 *L*a*b** colour-difference formula (ISO/CIE 11664-4) with corrections for variation in colour-difference perception dependent on lightness, chroma, hue and chroma-hue interaction. Reference conditions define material and viewing environment characteristics to which the formula applies.

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Colorimetry – — Part 6: CIEDE2000 colour-difference formula

1 Scope

This ~~International Standard~~document specifies the method of calculating colour differences according to the CIEDE2000 formula.

~~The~~This document is applicable to input values of CIELAB L^*, a^*, b^* coordinates calculated according to ISO/CIE 11664-4. ~~The document may~~It can be used for the specification of the colour difference between two colour stimuli perceived as belonging to reflecting or transmitting objects. This includes displays~~,~~ if they are being used to simulate reflecting or transmitting objects and if the tristimulus values representing the stimuli are appropriately normalized. ~~The~~

This document does not apply to colour stimuli perceived as belonging to areas that appear to be emitting light as primary light sources~~,~~ or that appear to be specularly reflecting such light.

2 Normative references

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The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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~~CIE 142-2001. *Improvement to industrial colour-difference evaluation*, 2001.~~

ISO/CIE 11664-4, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

CIE S 017~~.~~, *ILV: International Lighting Vocabulary*~~.~~

~~ISO/CIE 11664-4 *Colorimetry – Part 4: 1976 L*a*b* Colour Space*.~~

43 Terms and definitions

For the purposes of this document, the terms and definitions given in CIE S 017 apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

CIE maintains a terminology database for use in standardization at the following address:

— CIE e-ILV: available at https://cie.co.at/e-ilv~~https://cie.co.at/e-ilv~~

54 Symbols ~~and abbreviated terms~~

~~*L** CIELAB lightness~~

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~~a^*, b^* CIELAB a^*,b^* coordinates~~

~~CIELAB chroma~~

~~CIELAB hue angle~~

~~L' CIEDE2000 lightness~~

~~arithmetic mean of the CIEDE2000 lightnesses of two colour stimuli~~

~~a', b' CIEDE2000 a', b' coordinates~~

~~C' CIEDE2000 chroma~~

~~arithmetic mean of the CIEDE2000 chromas of two colour stimuli~~

~~h' CIEDE2000 hue angle~~

~~arithmetic mean of the CIEDE2000 hue angles of two colour stimuli~~

~~G switching function used in the modification of a^*~~

~~$\Delta L'$ CIEDE2000 lightness difference~~

~~$\Delta C'$ CIEDE2000 chroma difference~~

~~$\Delta h'$ CIEDE2000 hue-angle difference~~

~~$\Delta H'$ CIEDE2000 hue difference~~

~~ΔE_{00} CIEDE2000 colour difference~~

~~S_L lightness weighting function~~

~~S_C chroma weighting function~~

~~S_H hue weighting function~~

~~T T-function for hue weighting~~

~~R_T rotation function~~

~~$\Delta\theta$ hue dependence of rotation function~~

~~R_C chroma dependence of rotation function~~

~~k_L lightness parametric factor~~

~~k_C chroma parametric factor~~

~~k_H hue parametric factor~~

L^* CIELAB lightness

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a^*, b^*	CIELAB a^*, b^* coordinates
C^*_{ab}	CIELAB chroma
h_{ab}	CIELAB hue angle
L'	CIEDE2000 lightness
$\overline{L'}$	arithmetic mean of the CIEDE2000 lightnesses of two colour stimuli
a', b'	CIEDE2000 a', b' coordinates
C'	CIEDE2000 chroma
$\overline{C'}$	arithmetic mean of the CIEDE2000 chromas of two colour stimuli
h'	CIEDE2000 hue angle
$\overline{h'}$	arithmetic mean of the CIEDE2000 hue angles of two colour stimuli
G	switching function used in the modification of a^*
$\Delta L'$	CIEDE2000 lightness difference
$\Delta C'$	CIEDE2000 chroma difference
$\Delta h'$	CIEDE2000 hue-angle difference
$\Delta H'$	CIEDE2000 hue difference
ΔE_{00}	CIEDE2000 colour difference
S_L	lightness weighting function
S_C	chroma weighting function
S_H	hue weighting function
T	T-function for hue weighting
R_T	rotation function
$\Delta\theta$	hue dependence of rotation function
R_C	chroma dependence of rotation function
k_L	lightness parametric factor
k_C	chroma parametric factor
k_H	hue parametric factor

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~~6~~5 Reference conditions

The CIEDE2000 formula is intended to be applicable to objects viewed under the following reference conditions:

— Illumination: source simulating the relative spectral irradiance of CIE Standard Illuminant D65.

— Illuminance: 1 000 lx.

— Observer: normal colour vision.

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— Background field: uniform, neutral grey with L^* = 50.

— Viewing mode: object.

— Sample size: sample pair subtending a visual angle greater than 4°.

— Sample separation: minimum sample separation achieved by placing the sample pair in direct edge contact.

— Sample colour-difference magnitude: 0 to 5 CIELAB units.

— Sample structure: homogeneous colour without visually apparent pattern or non-uniformity.

When conditions of use deviate appreciably from the reference conditions, parametric factors may be used to correct for the effects of material or experimental variables, as described in Clause 6.

NOTE CIE 230:2019 discusses and shows some application limitations of CIEDE2000 for CIELAB colour differences ≤ 2 units.

6 Calculation method

All angular quantities in this document shall be evaluated in degrees.

CIELAB L^*, a^*, b^* and C^*_{ab} coordinates of the two samples shall be calculated according to ISO/CIE 11664-4.

Modified CIELAB coordinates shall be calculated according to Formulae (1) to (7).

$$L' = L^* \quad (1)$$

$$a' = (1+G)\,a^* \quad (2)$$

$$b' = b^* \quad (3)$$

$$C' = (a'^2 + b'^2)^{1/2} \quad (4)$$

$$h' = \begin{cases} \arctan\left(\dfrac{b'}{a'}\right) & \text{if} \quad a' > 0 \quad \text{and} \quad b' \geq 0 \\ \arctan\left(\dfrac{b'}{a'}\right) + 360° & \text{if} \quad a' > 0 \quad \text{and} \quad b' < 0 \\ \arctan\left(\dfrac{b'}{a'}\right) + 180° & \text{if} \quad a' < 0 \\ 90° & \text{if} \quad a' = 0 \quad \text{and} \quad b' > 0 \\ 270° & \text{if} \quad a' = 0 \quad \text{and} \quad b' < 0 \end{cases} \quad (5)$$

$$h' = 0° \text{ if} \quad a' = 0 \quad \text{and} \quad b' = 0 \quad (6)$$

where

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